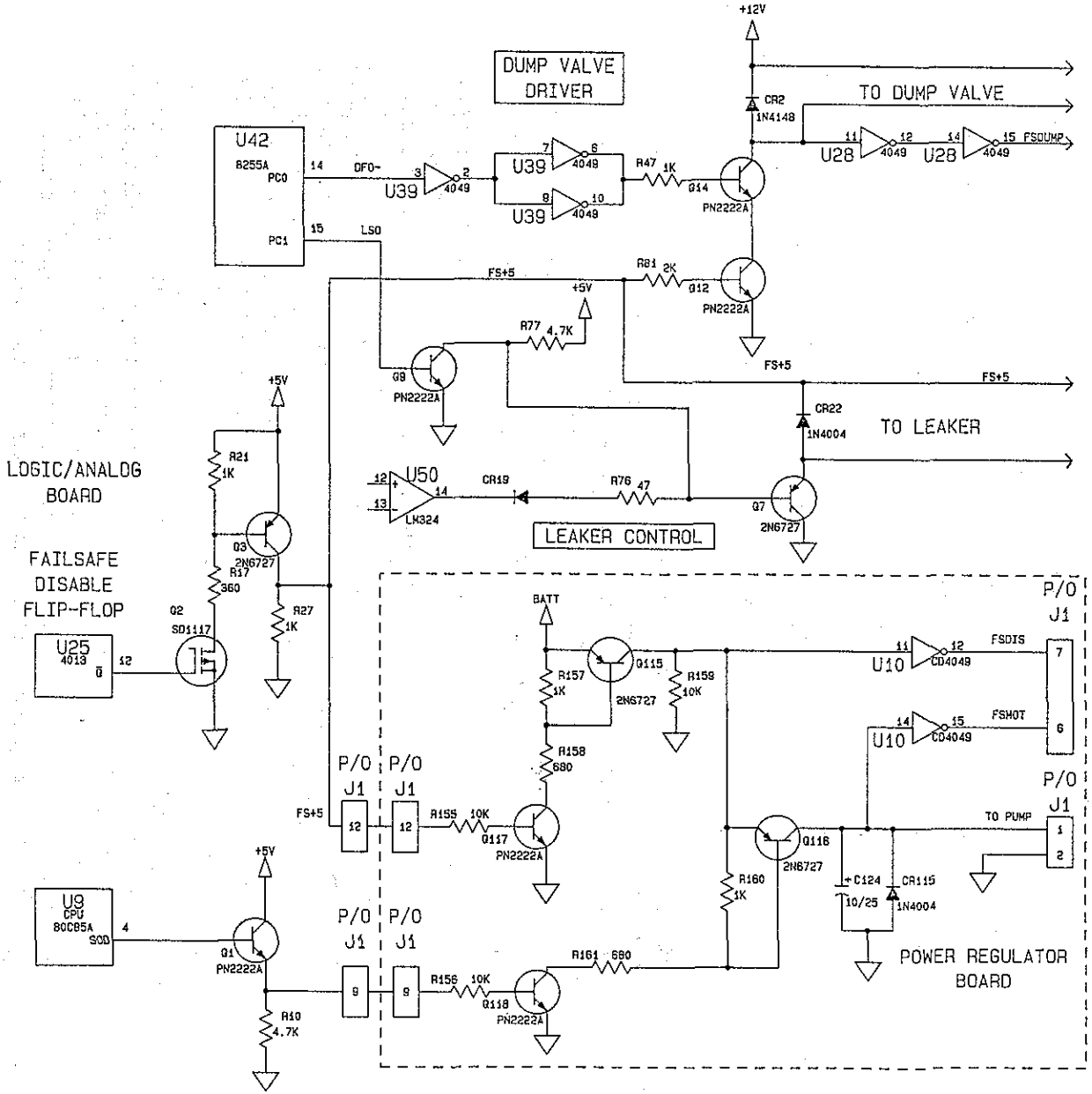

Figure 3-22B. Failsafe Circuit

3.9.2 Battery Charger Regulator (figure 3-25)

When the instrument is plugged in to an AC power source, the battery charger regulator serves to charge the battery at all times and provides operating power to the instrument when it is turned on.

This circuit is a switching regulator based on a TL-494 regulator (U101), driving pass transistors Q101 and Q102 with a pulse width modulated signal. L101 stores energy when Q101 is turned on and releases energy through commutating diode CR108 when Q101 is turned off. C106 smooths the voltage at the output side of L101. Output current limiting to nominally 2 amps maximum is accomplished by measuring the voltage drop across R108 at pins 1 and 2 of U101 via the network consisting of R112 and R119.

Voltage feedback is through R120, R121 and R122 which form an adjustable divider, allowing the output voltage to be precisely set. The reference voltage is derived from pin 14 of U101 and supplied via R114 to pin 15.

This current and voltage feedback internally adjusts the pulse width driving Q101 such that an appropriate amount of energy is deposited in L101 to maintain the voltage across C106 at a constant value. For example, if the load were to increase on the regulator, this would cause the voltage at C106 to decrease, decreasing also the voltage at U101 pin 16 with regard to the reference voltage at pin 15. U101 would then increase the pulse width driving Q101, increasing the energy stored in L101, thus restoring the voltage level at C106. The switching frequency driving Q101 is determined by C111 and R113. When the instrument is turned off, the switching frequency-free runs at about 20 kHz. Q105 will be turned off at this time. When the instrument is turned on, a differentiated pulse of 23.4 kHz is applied to Q105, causing the switching frequency to lock at 23.4 kHz. The 23.4 khz frequency is a submultiple of the CPU clock frequency, thus the switching regulator is synchronized to the CPU clock, alleviating problems caused by asychronous noise injected into the instrument by the switching regulator.

Q107 is included to prevent the battery from draining back through the charger regulator to ground when the instrument is disconnected from AC power. When AC power is disconnected, the voltage across C102 is drained by the regulator and CR106 and R101, effectively turning off Q107. When Q107 is off, the regulator is disconnected from the system ground and current drain cannot occur.

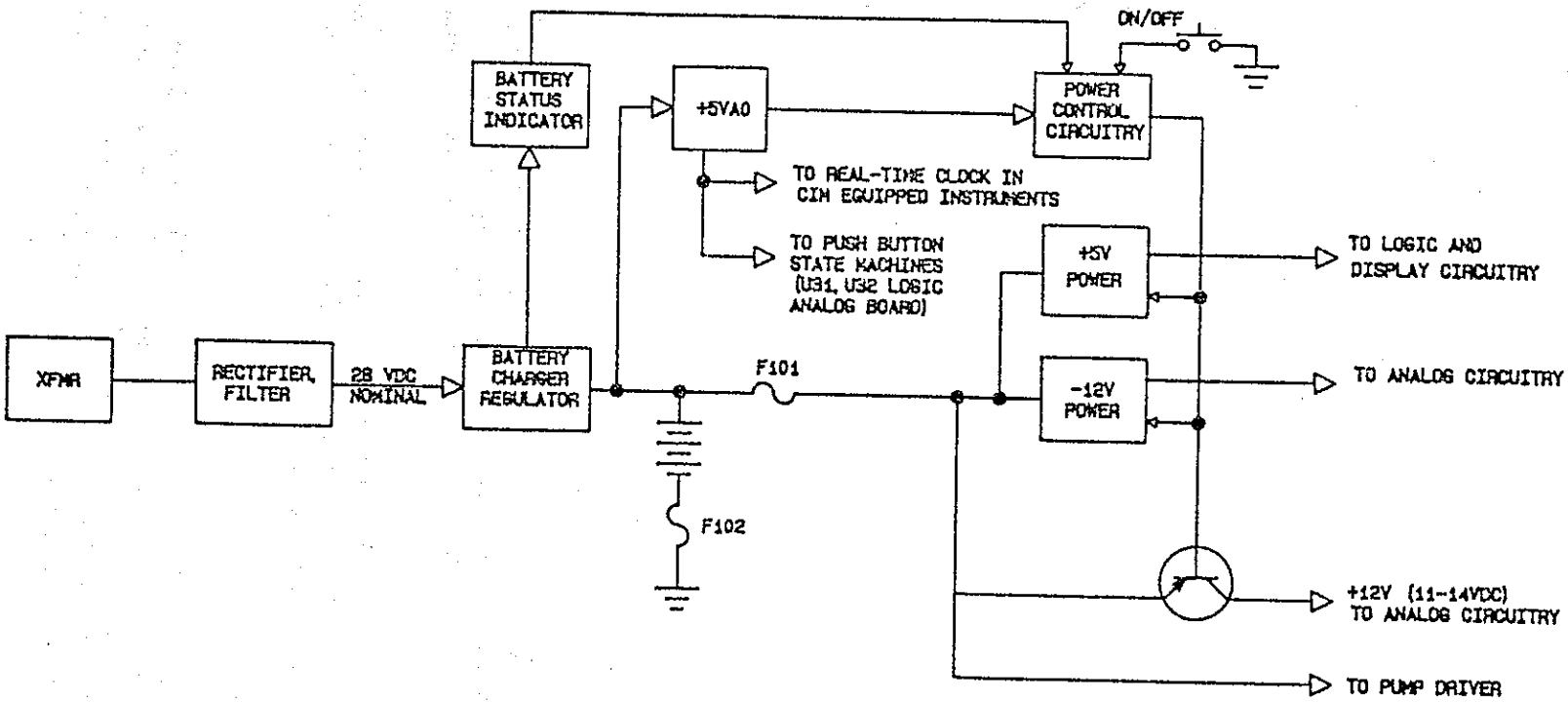

Figure 3-23. Block Diagram of Power Supplies

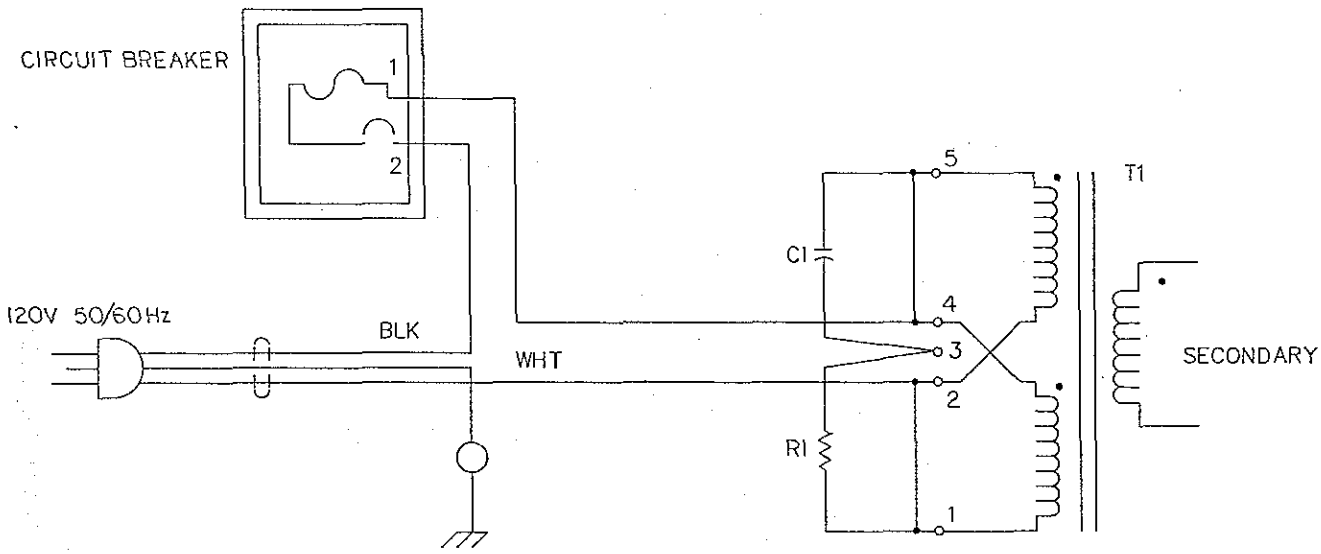

Figure 3-24. AC Power Connection

CR105 blocks the battery voltage from reaching C102. With the instrument connected to AC power, the voltage at C102 reaches about 28 VDC, causing CR106 to conduct, biasing Q107 on to complete the ground circuits for U101 and associated circuitry; enabling the battery charger regulator.

CR109 protects the battery and the rest of the instrument from overvoltage in case of failure of the regulator, such as might occur if Q101 were shorted.

3.9.3 Fuses (figure 3-25)

Two fuses are in the battery circuit. F101, a 2.5 amp fuse, protects against a fault in the power regulator or somewhere else in the power distribution system in the instrument. F102, a 5 amp fuse, protects the battery and associated circuitry in case of a direct short to ground from the battery.

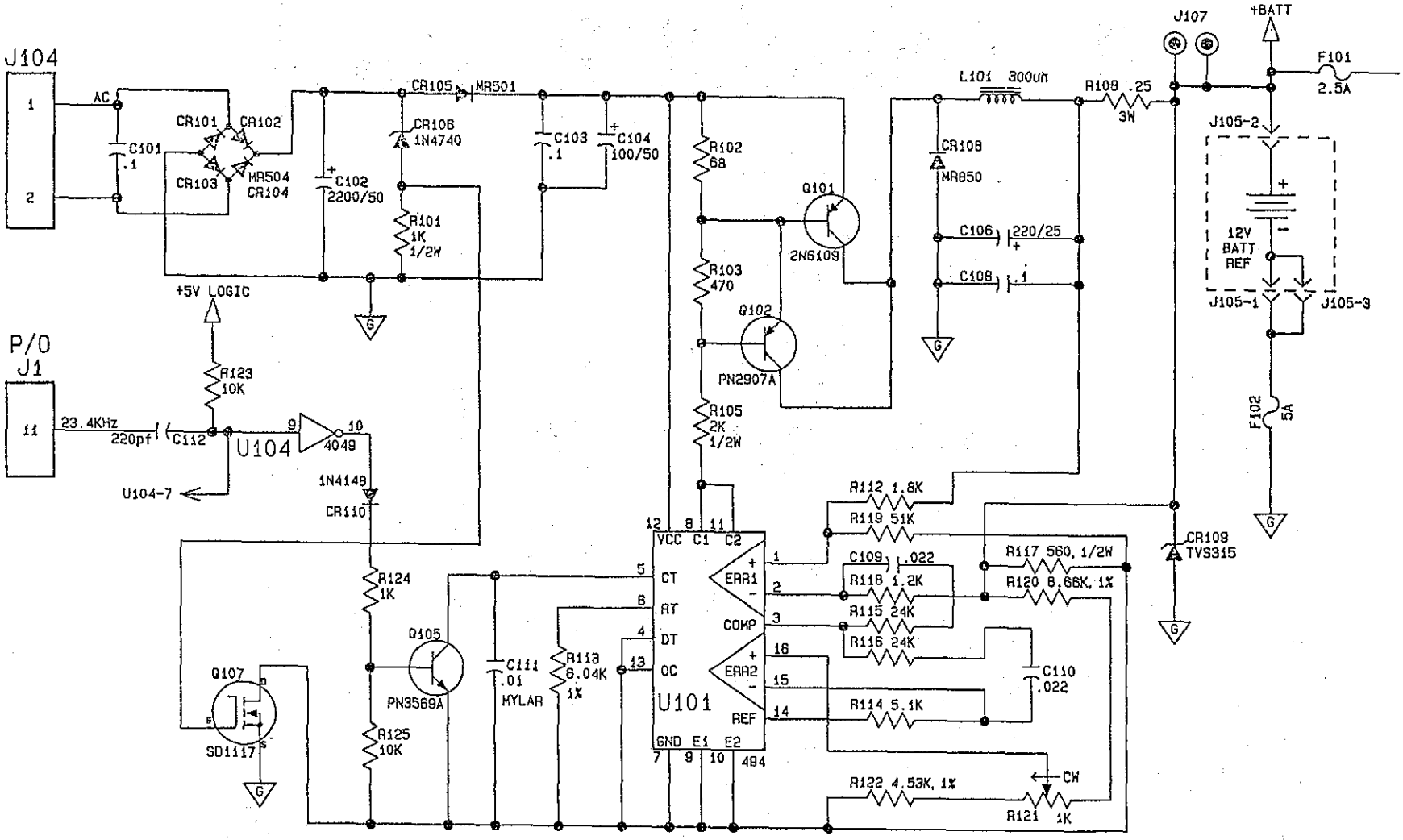

Figure 3-25. Rectifier, Line Regulator, and Battery Charger

3.9.4 Battery Charge Indicator (figure 3-26)

CR107, Q103, C105, R106, and C107 detect the switching waveform at Q101 collector, indicating that the instrument is plugged in and the switching regulator is functioning, thus charging the battery. Q103 will be turned on in this case, supplying current through R107, illuminating the charge indicator LED on the display/thermometer board. This also turns on Q104 through R109 to send a logic LO to port U40 on the logic/analog board, signaling the CPU that the instrument is operating on AC power.

3.9.5 Battery Status Monitor (figure 3-27)

The battery condition is monitored by three comparators, U106 pins 1, 2, and 14. VR101 provides a reference voltage to the comparators. If the battery voltage drops below 11.6 volts, the voltage at the junction of R145 and R146 will drop below the reference voltage resulting in U106 pin 1 going HI, and U104 pin 4 going LO. Similarly, if the battery drops below 11.5 volts, the voltage at the junction of R144 and R145 will drop below the reference voltage causing U106 pin 2 to go HI and U104 pin 2 to go LO. The signals from U104 pins 2 and 4 are monitored by the CPU through port U40 on the logic/analog board. If the voltage drops below 11.4 volts, the voltage at the junction of R143 and R144 will drop below the reference voltage. This causes U106 pin 14 to go LO, discharging C115, setting flip-flop U103 pins 4 and 10, disabling the instrument (figure 3-28).

C115 and R147 prevent short-term voltage drops from, for example, the pump motor load, from turning off the instrument. Table 3-6 summarizes the comparator reference thresholds.

Table 3-6. Battery Status Monitor Reference Thresholds

Battery < 11.6V, U106-1	= HI (i.e., LOWBATT- = LO)
Battery < 11.5V, U106-2	= HI (i.e., DEADBAT- = LO)
Battery < 11.4V, U106-14	= LO (i.e., RESET- = LO)

The voltage source to the battery status monitor comes from part of the power-on circuit.

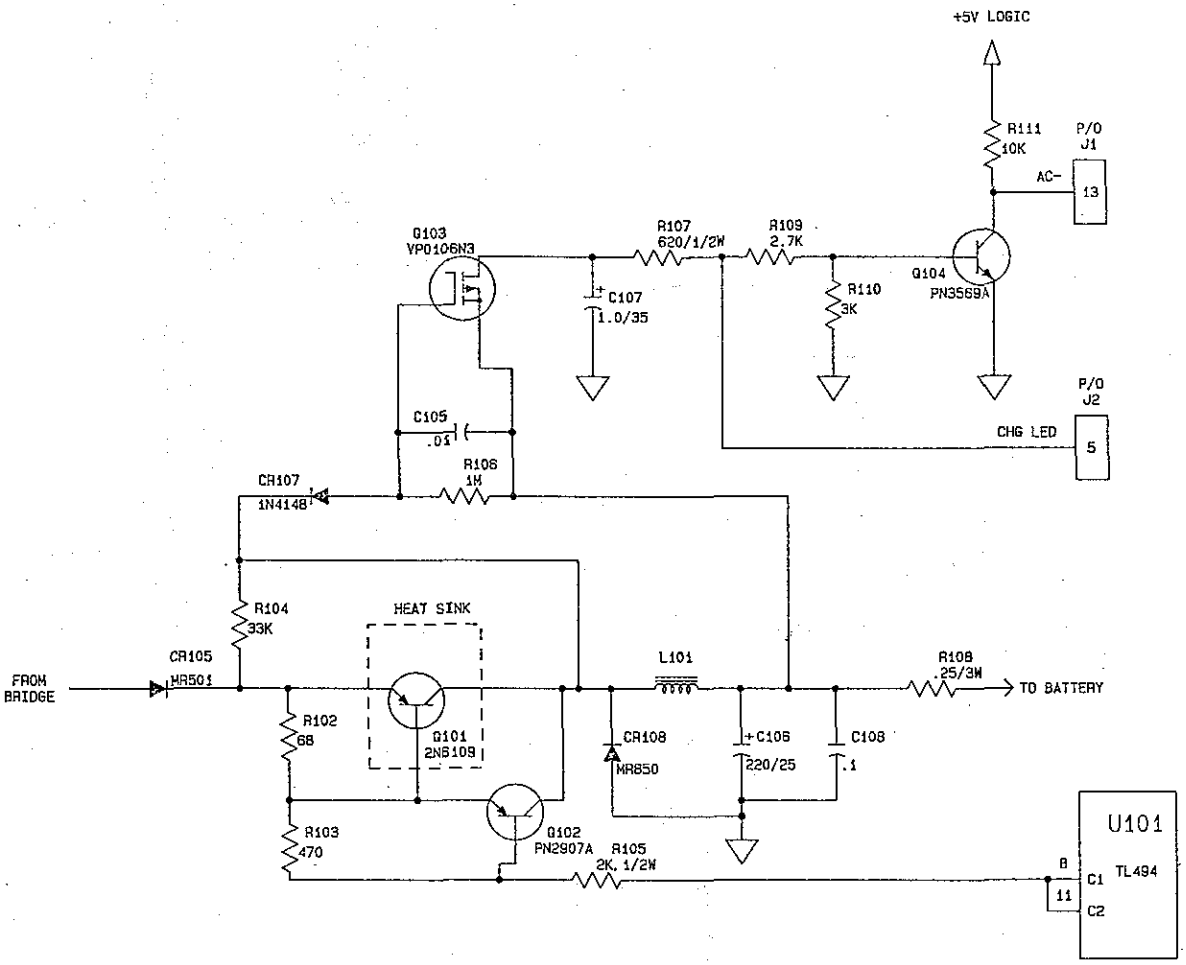

Figure 3-26. Battery Charge Indicator

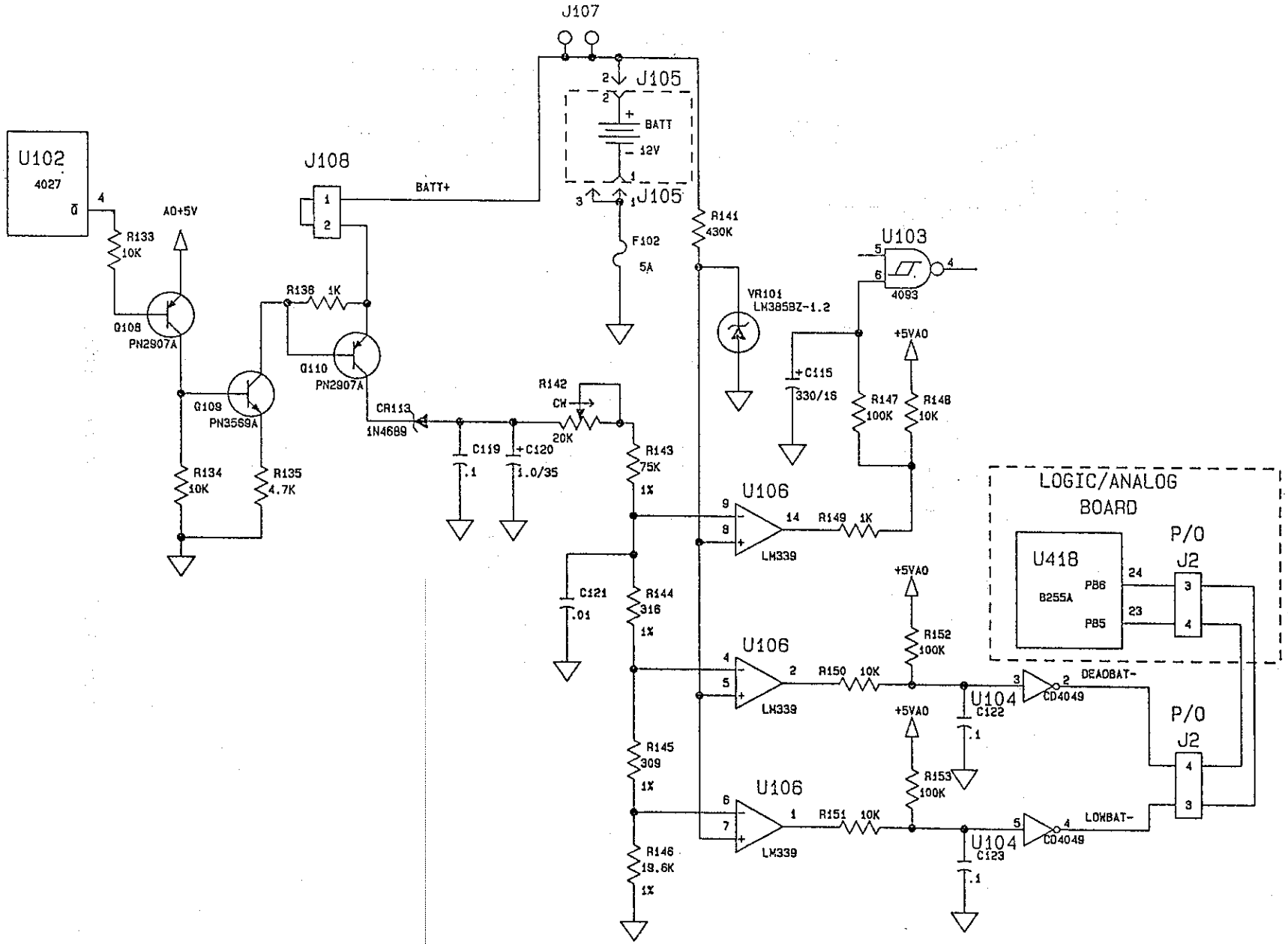

Figure 3-27. Battery Status Monitor

3.9.6 Power On/Off Control (figure 3-28)

The instrument is turned on or off electronically rather than with an electro-mechanical switch. However, a pushbutton is used to actuate the electronic switching.

U102, a JK flip-flop, is the main control element. In normal operation, U102 is toggled (changes state) every time the ON/OFF switch is activated. R128, R127, C113 and U103-11, a Schmitt trigger, debounce the ON/OFF switch and apply a clock pulse to U102-13 upon ON/OFF switch activation. If the instrument was previously turned off, U102 will toggle so that the Q output, pin 15, will go HI and the $\overline{Q}$ output, pin 14, will go LO. The high Q output is applied to the logic board through J1-10 (PWRON) and to the base of Q122, turning on the +12V power supply, which in turn enables the +5 logic and -12V power supplies and powers up the instrument. Actuating the power switch again will reverse the above process.

The +12V and +5V power supplies are discussed further in sections 3.9.7 and 3.9.8.

The LO $\overline{Q}$ output of U102 is applied through R133 to Q108, turning it on, which then turns on Q109 and Q110 to apply battery voltage to the battery status comparators, U106 pins 1, 2, and 14, through the divider chain CR113, R142, R143, R144, R145, and R146. The battery status circuitry is described in section 3.9.5 (figure 3-27).

The battery status circuit can hold U102 reset. U103-4 and U103-10 are configured as an R/S flip-flop which can be set to prevent U102 from being toggled to turn the instrument on. If the battery voltage drops below 11.4 volts, the battery status output (U106-14) will go LO. This LO is coupled through R147, discharging C115 and causing U103-4 and U103-10 to be set with pin 10 LO and pin 4 HI. The LO level from U103 pin 10 is coupled to U103 pin 1, causing U103 pin 3 to go HI, holding U102 reset and the instrument off. To reset U103-4 and U103-10, the instrument must be connected to an AC power source. This action turns on Q107, pulling CR112 LO, which pulls U103 pin 8 LO, resetting U103-4 and U103-10 so U103 pin 10 is HI and U103 pin 4 is LO.

The CPU can turn the instrument off by resetting U102. This is done via output U40 port on the logic/analog board turning on Q106, driving U103 pin 2 LO, causing U103 pin 3 to go HI, resetting U102.

The on/off control circuit is always active, and is powered by the +5VAO supply discussed in section 3.9.10.

3.9.7 +12 Volt Supply (figure 3-29)

The +12V supply is derived directly from the battery via Q123. Although labeled +12V, the actual voltage can be between about +11 to +14 volts, depending on the state of battery charge and whether the instrument is plugged in.

The pump motor is not powered by the +12V supply, but through its own switch, Q115 and Q116, directly from the battery via F101.

The power ON/OFF switch controls the +12V supply, which in turn controls the +5V Logic and -12V supply. To turn the instrument on, J/K flip-flop U102 is toggled by the ON/OFF switch. U102-15, the Q output, goes HI, and current flows to the base of Q122, which is configured as an emitter follower. Current then flows into Q122 collector from Q123 base, also turning on Q123, the +12 volt supply switch.

The current flowing through Q122 flows through R178 and also through Q121 base and Q114 base, turning them on. The +12V from Q123 collector is applied to U107 (+5V supply) and U108 (-12V supply) causing them to be enabled, supplying power to the rest of the instrument.

3.9.8 +5V Logic Supply (figure 3-29)

The +5V supply furnishes most of the logic Vcc potentials in the instrument, power to the displays, and power to the thermometer.

This supply is very similar to that of the battery charger regulator. It is powered from the battery voltage or battery charger regulator via F101. U108 drives the pass transistor, Q119, via Q120 and Q121 with a pulse width modulated signal at a 23.4 kHz rate. L103 is the energy storage inductor, CR116 is the commutating diode, and C136 serves as a filter capacitor.

CR117 is an overvoltage protection diode to protect the items on the 5 volt line in case of a regulator failure, such as a shorted Q119. C144 and R180 result in a free-running switching frequency of about 20 kHz, which is synchronized to 23.4 kHz, a submultiple of the 80C85 clock frequency, by a differentiated 23.4 kHz pulse via Q124.

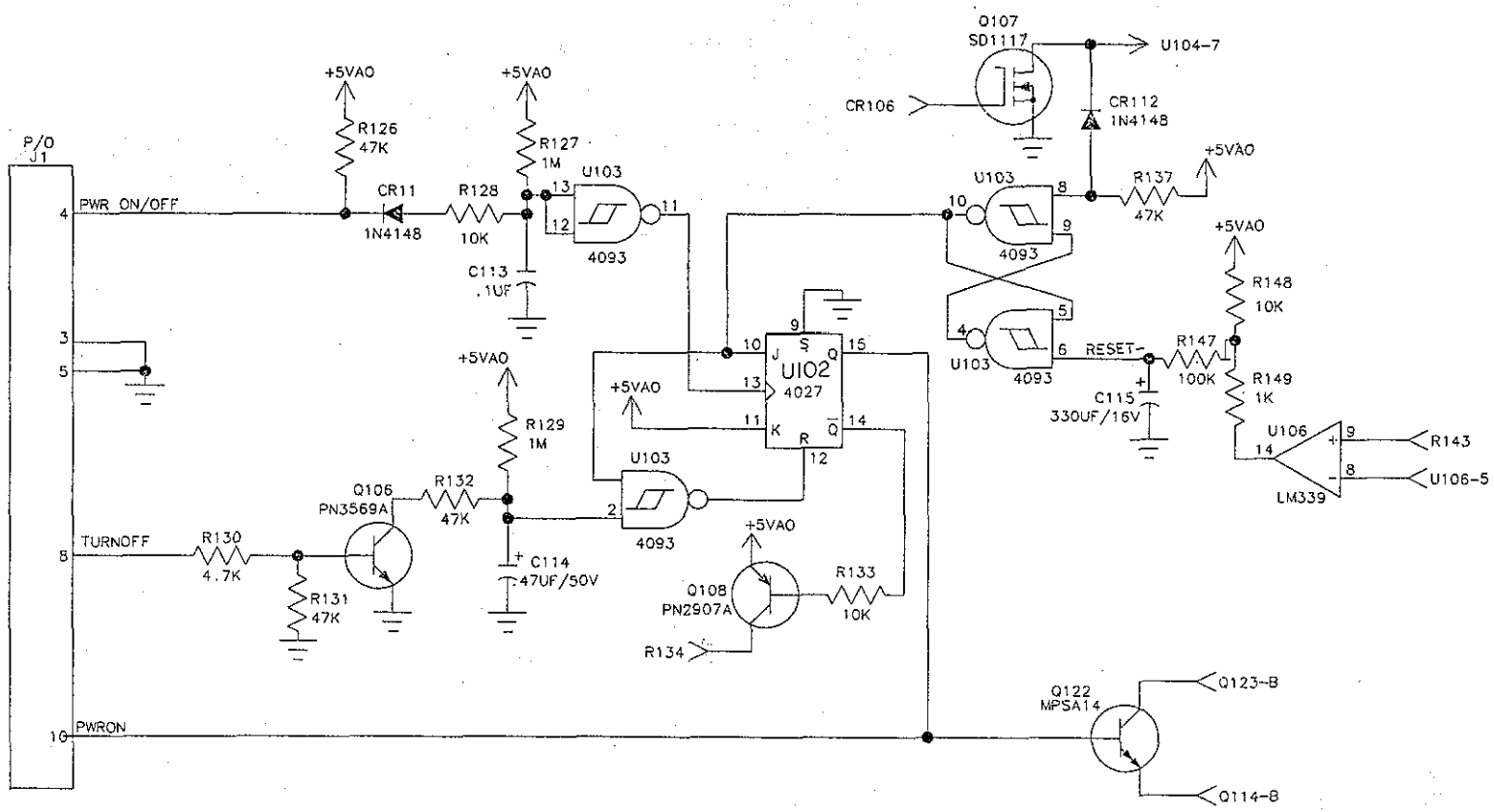

Figure 3-28. Power ON/OFF Control

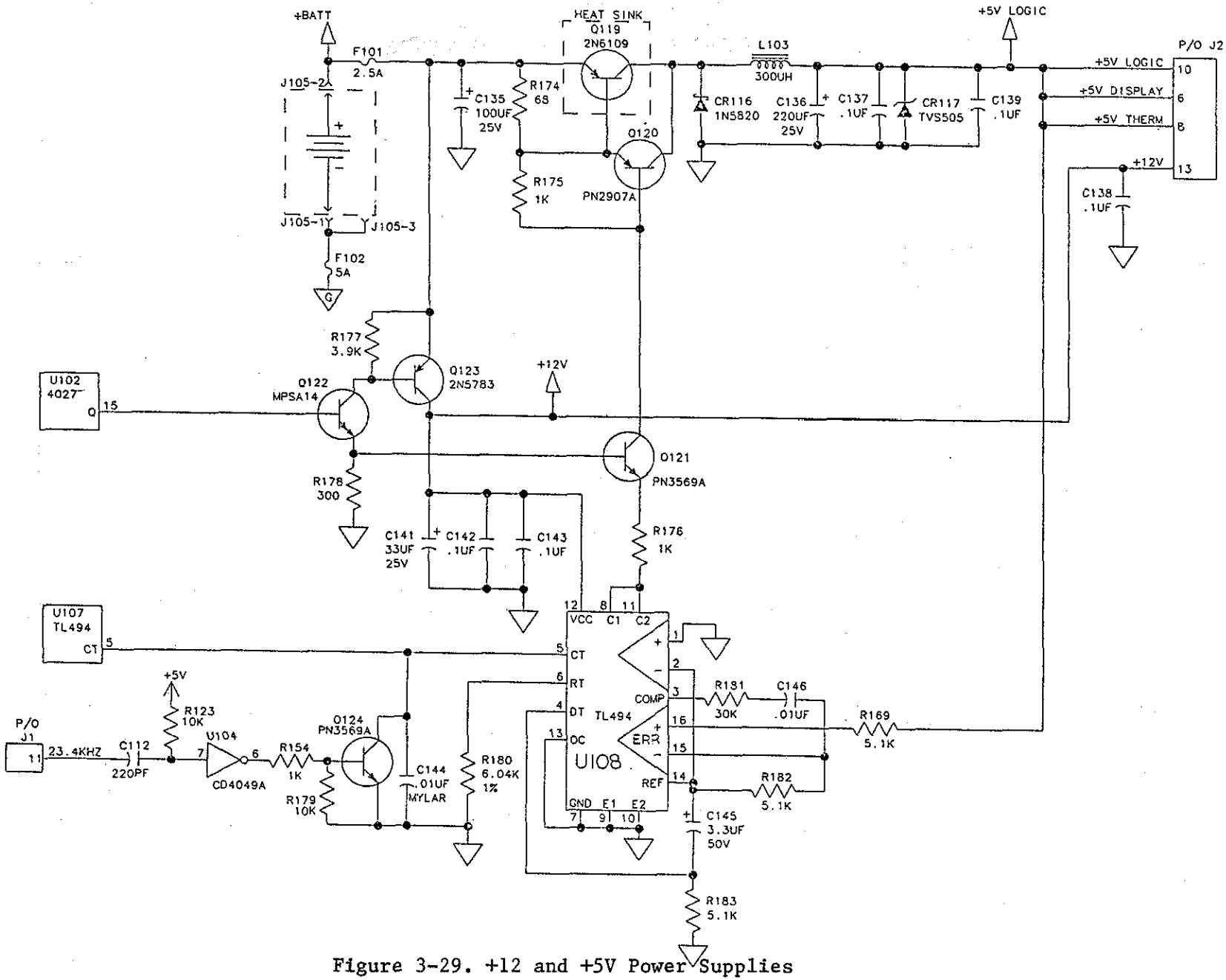

Figure 3-29. +12 and +5V Power Supplies

3.9.9 -12 Volt Supply (figure 3-30)

The -12V supply is used to supply negative bias voltages for the analog circuitry in the instrument. It is powered from the battery or battery charger regulator via F101.

This supply is a pulse width modulated type of flyback switching supply, capable of converting the positive battery voltage directly to a negative voltage. Q112 is the pass element, driven by U107 via Q113 and Q114 in the same manner as in the battery charger regulator. When Q112 conducts, energy is stored in L102. When Q112 is switched off, the energy stored in L102 causes the voltage at the L102 and CR114 junction to swing negative, forward biasing CR114 and charging C127. C127 serves as a filter capacitor. The negative voltage at C127 is compared with the reference voltage in U107 via R166, R167, R170 and R172. In the same manner as in the battery charger regulator, the switching pulse width is adjusted to maintain the output voltage at the correct level. There is no current-limiting feature in this supply. L104 and C128 and 129 form a noise filtering network. A synchronized 23.4 kHz ramp is supplied to U107 pin 5 from U108 pin 5.

3.9.10 +5 Volt Always-On Supply (+5VAO, figure 3-31)

This supply is a small linear regulated supply designed to run directly from the battery/battery charger voltage. It is used to maintain power at all times on the always-active components used for the power ON/OFF control, and also used to power the real-time clock and oscillator on the CIM equipped instruments and the pushbutton state machines (U31 and U32).

VR101, a reference diode, is used as a 1.24V reference. Q111 is the pass element, with the +5VAO potential available at its source connection. U105, a transistor array, is configured as a differential amplifier, comparing the +5VAO potential via R138 and R139 with the 1.24V reference. The resultant error signal drives the gate of Q111 to maintain the +5VAO value.

This circuit is designed to draw very little overhead current so as not to load the battery.

3.10 THERMOMETER FUNCTIONS (figure 3-32)

3.10.1 Temperature Measurement

The display/thermometer board is an essentially independent measuring system, containing its own hardware and software. Once activated by removal of the thermometer probe from its socket, a measurement cycle is initiated. The thermometer probe sends an analog temperature signal to the module. The signal is processed by signal conditioning circuitry and is digitized into groups of three BCD words by the A/D converter. This data is used by the µcontroller to compute and display the temperature.

As shown in the block diagram (figure 3-32) the analog temperature signal is linearized and converted to BCD. The µcontroller reads the data through the multiplexer, and writes the temperature to the display. The thermometer module also contains a power control circuit so that internal power on the board is off when not in use.

3.10.2 µController (U1, figure 3-33)

The µcontroller (U1) is an NSC COP444L customized IC. It contains 2K bytes of ROM, 128 bytes of RAM, an internal clock generator, timing registers, and I/O porting for data acquisition and display writing.

The µcontroller reads and processes digital temperature data from the A/D converter and writes temperature display data to the display driver board. Self-contained software uses four bit-words to process data.

In addition, the µcontroller operates the display/thermometer board speaker (LS1), and reads and processes settings of the NORMAL/MONITOR mode switch, the S2 internal DIP switch no. 5 (°F/°C), and the DISPLAY TEST switch.

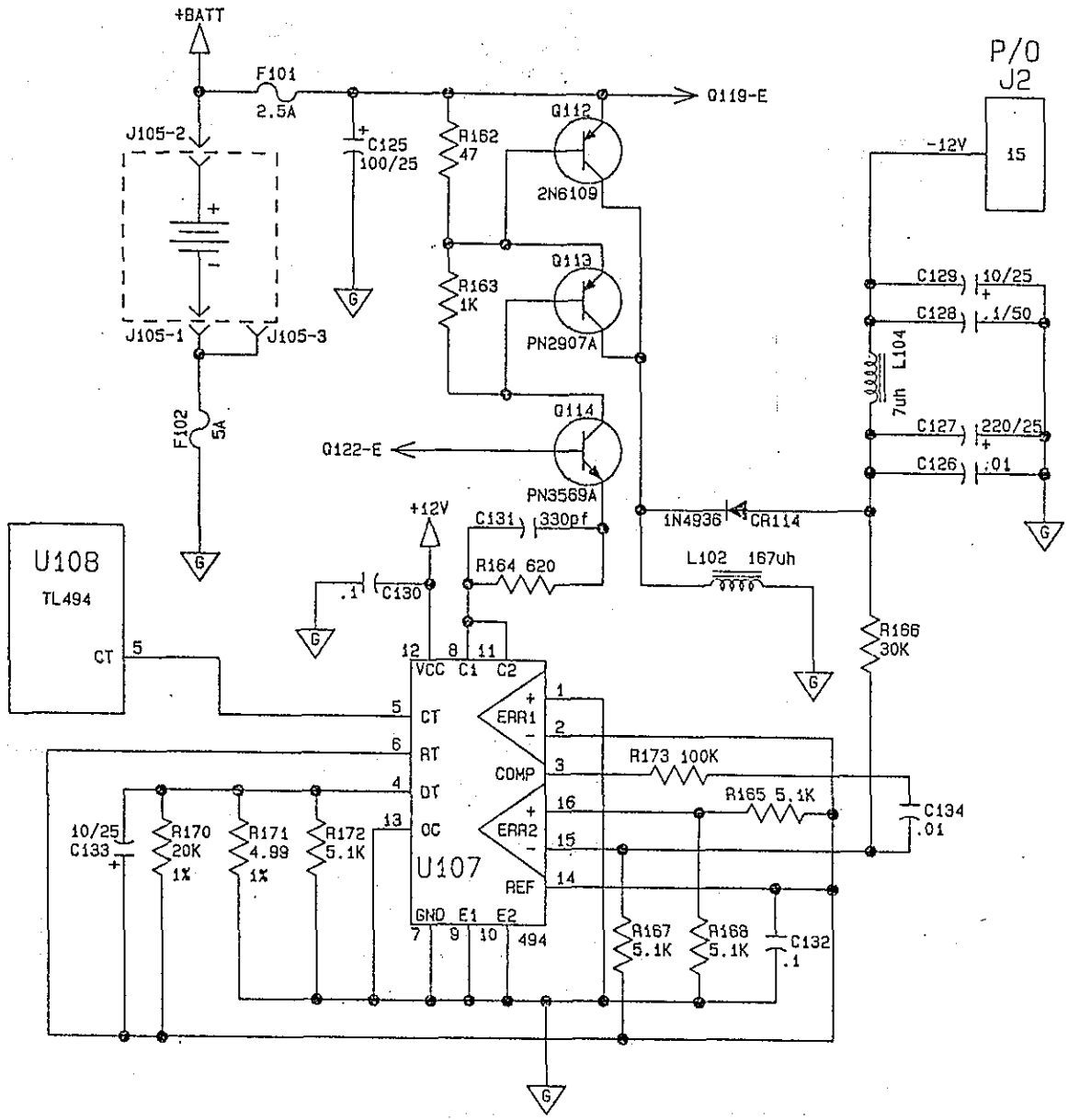

Figure 3-30. -12V Supply

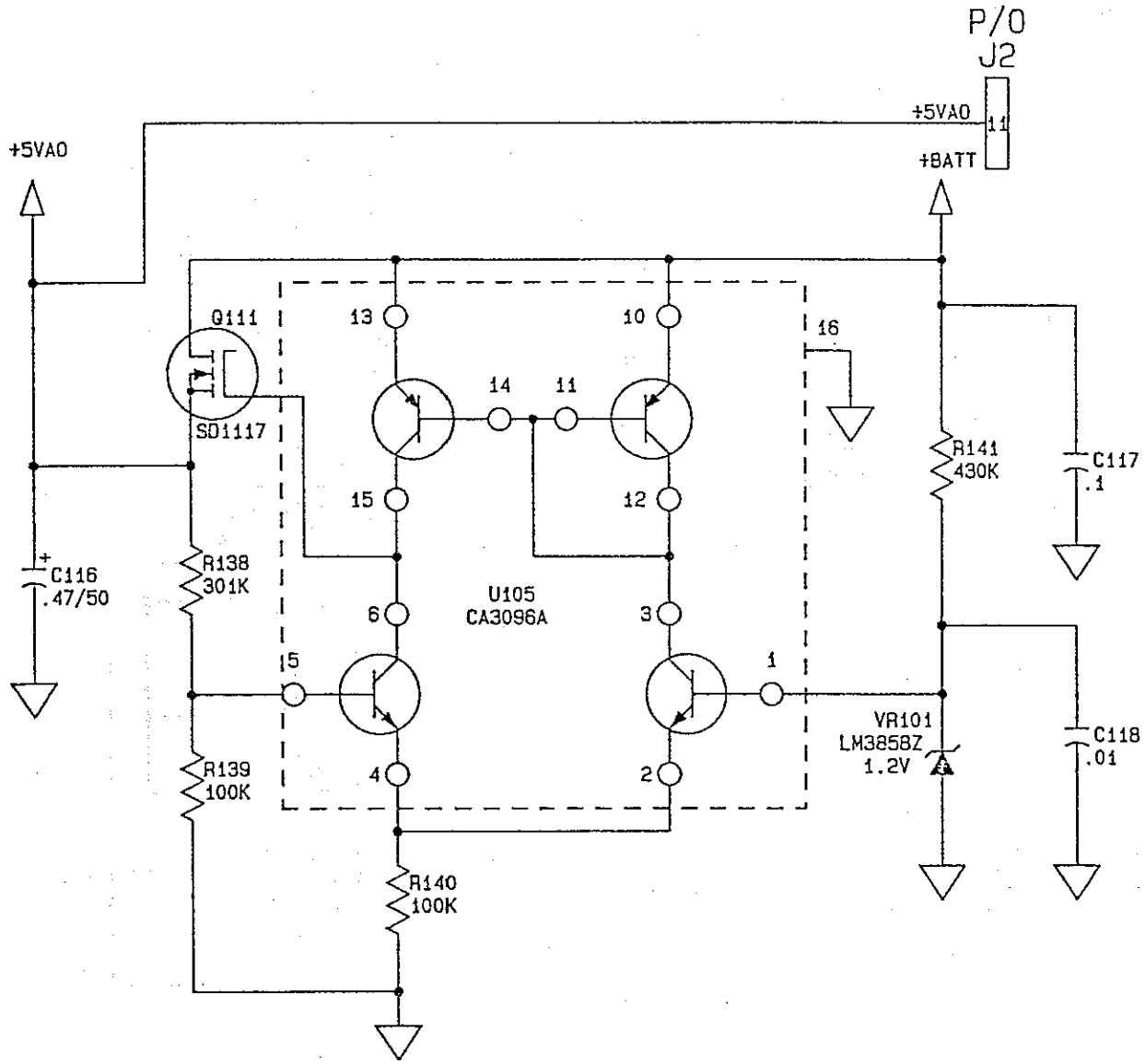

Figure 3-31. +5V Always-On Supply

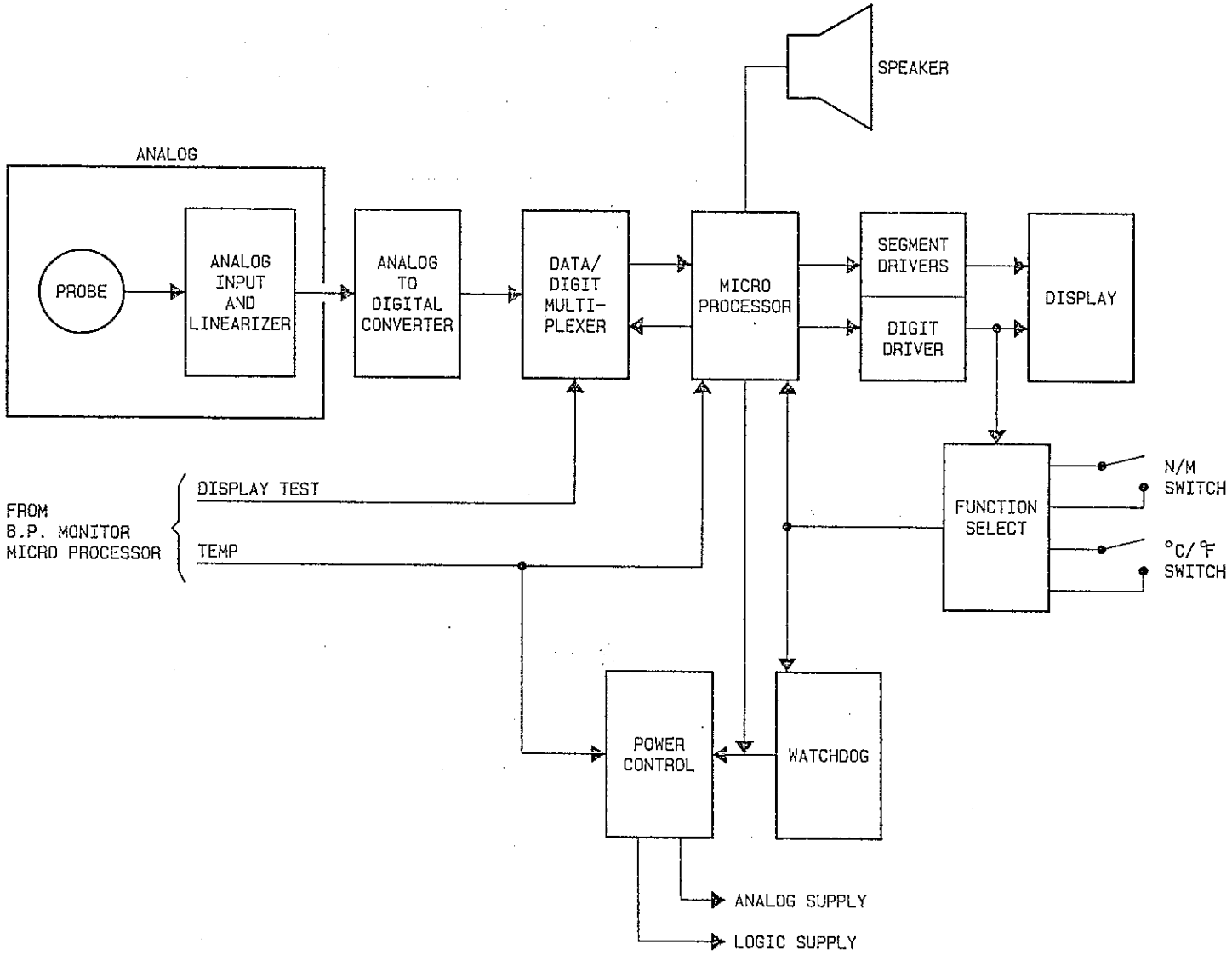

Figure 3-32. Block Diagram of the Thermometer

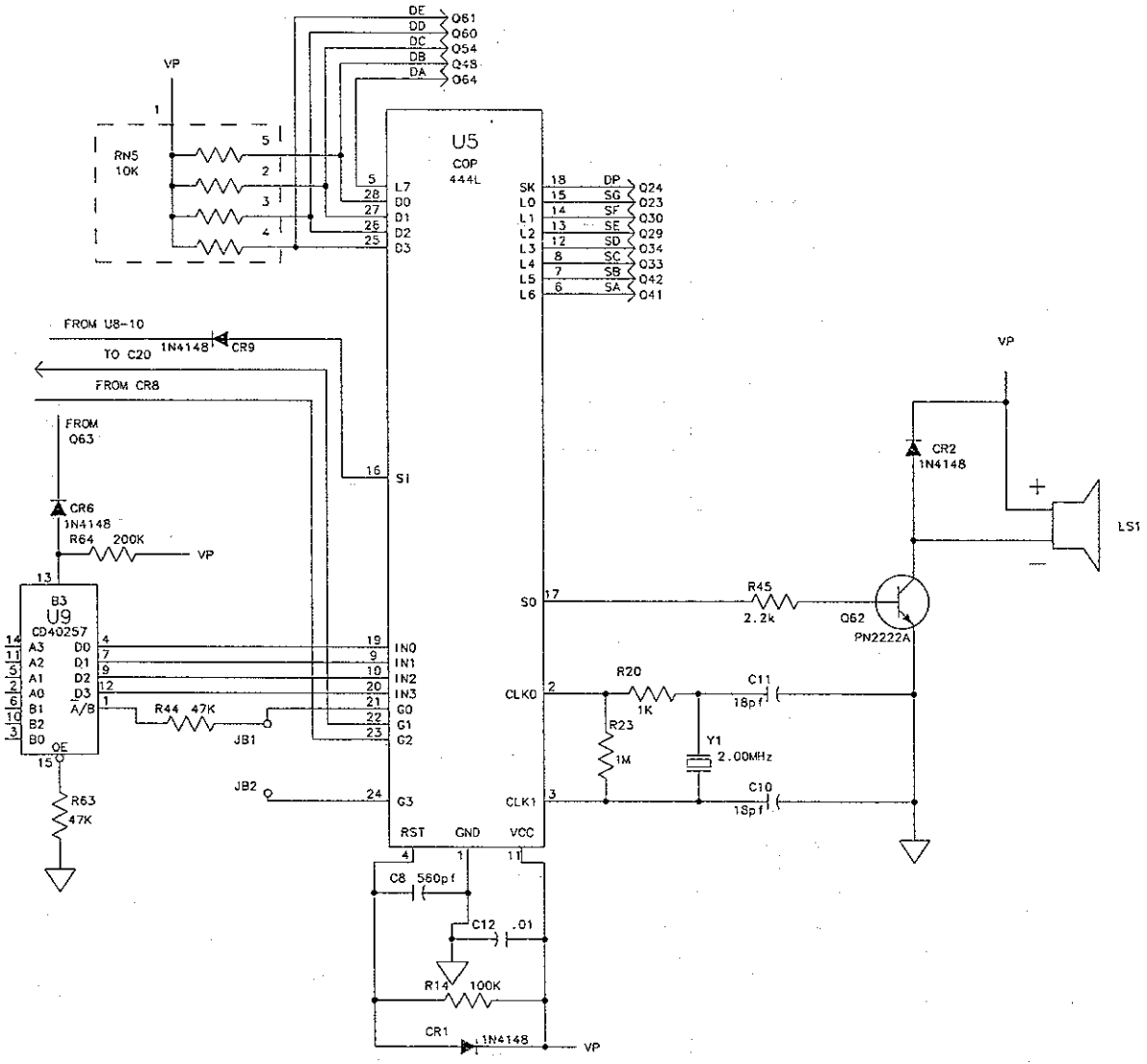

Figure 3-33. Thermometer µController

The thermometer µcontroller, U5, is an independent system, measuring temperature and controlling the temperature display without processing by the CPU. Only the thermometer probe sense signal, which is used to turn the thermometer board on at the beginning of a measurement cycle, and display test command is received from the CPU.

The µcontroller is configured as follows:

- Inputs IN0 through IN3 receive data from D0 through D3 outputs of multiplexer U9 regarding temperature, digit strobe (LSD, NSD, and MSD), and display test state (on or off) via U9-13.

- The G port (G0 through G3) has both inputs and outputs. G0 is an output which selects the multiplexer channel, data (A0 through A3), or digit strobe and display test state (B0 through B3), to be read at the U5 IN port. G1 is an output which resets the power control flip-flop for automatic turn-off of the thermometer when a temperature measurement is completed or the probe is inserted into the storage well. G2 is an input which senses the state of the probe sense signal via the CPU; G3 is an input used for testing purposes.

- Serial I/O register S0 is an output that turns on Q62, causing the speaker to be activated when it conducts.

- CLK0 and CLK1 are the external inputs for the clock generator, which utilizes a 2.00 MHz crystal. Capacitors C10 and C11 establish the load for the crystal. The crystal frequency is internally divided by 32 to achieve the 16 microsecond cycle time of the µcontroller. This cycle time ensures that the routines of the programs within the µcontroller execute at the proper rate.

- RST input, with C8 and R14 performs the power-on initialization.

  Outputs L0 through L6 are the display segment drivers. Outputs D0 through D3 and L7 are the display digit drivers. The display decimal point is driven from output SK.

3.10.3 Analog Input and Linearizer (figure 3-34)

The analog input and linearizer consists of U7-5, 6, and 7; voltage regulator U13; resistors R53, R54, R55, R67, R68, R69, R70, R71, and R72; wide-band choke L1; and capacitors C18, C23, and C24. The voltage at U7-7 is linearly proportional to the temperature of the probe tip. Filtering of noise and stray interference is provided by L1, C24, C18, and C23.

As the temperature of the probe tip rises, the resistance of the thermistor, Rt, decreases nonlinearly. This varying resistance leads to a changing voltage which is applied to the REF terminal of U13 from U7-7. From the OUT terminal, the voltage goes through R71, R72, and the probe circuit. The output of U13-3 is also applied to U7-5 via R71. These resistors are configured as a bridge whose output is applied to the differential inputs of operational amplifier (op amp) U7 at pins 5 and 6. This amplifier's gain is set by R55 and R54. This circuit scales the voltage to a range of 0 to 1 VDC, which is the voltage level accepted by the A/D converter at U6-11.

The output voltage from U7-7 is applied to the REF terminal of U13 via R53, as well as to U6-11. The loop through R53, REF, and OUT of U13 compensates for the nonlinear resistance versus temperature of the thermistor. The voltage regulator U13 always maintains the OUT voltage 1.2V higher than the REF voltage, which drives the top of the bridge at R71 and R3 of the probe. The effect of the loop through R53, REF, and OUT is to increase the voltage applied to the top of the bridge as the temperature of the probe tip rises. The output voltage at U7-7 is 0.000 to 1.000V with respect to U6-10, with 0.000V corresponding to 31.1°C (88.0°F) and 1.000V corresponding to 42.2°C (108°F).

3.10.4 A/D Converter (U6, figure 3-35)

U6 is a self-contained, dual-slope A/D converter which converts voltage from the analog circuit to binary coded decimal (BCD) form which the µcontroller can use. The signal input range is 0.000 to 1.000 VDC. The A/D converter contains a three-decade BCD counter which is used to determine a digital output indicating between 0.000V and 0.999V input. At the beginning of a conversion cycle C22 charges at a rate proportional to an internal reference voltage. C22 then discharges at a rate proportional to the input voltage. The counter counts until C22 discharges. The total count is then sent to the µcontroller via multiplexer U9.

U6-10 and 11 are a differential input for voltage signals from the analog circuitry. The span or range of data conversion is trimmed by variable resistor R83 (SPAN) which adjusts a reference current utilized internally by the converter.

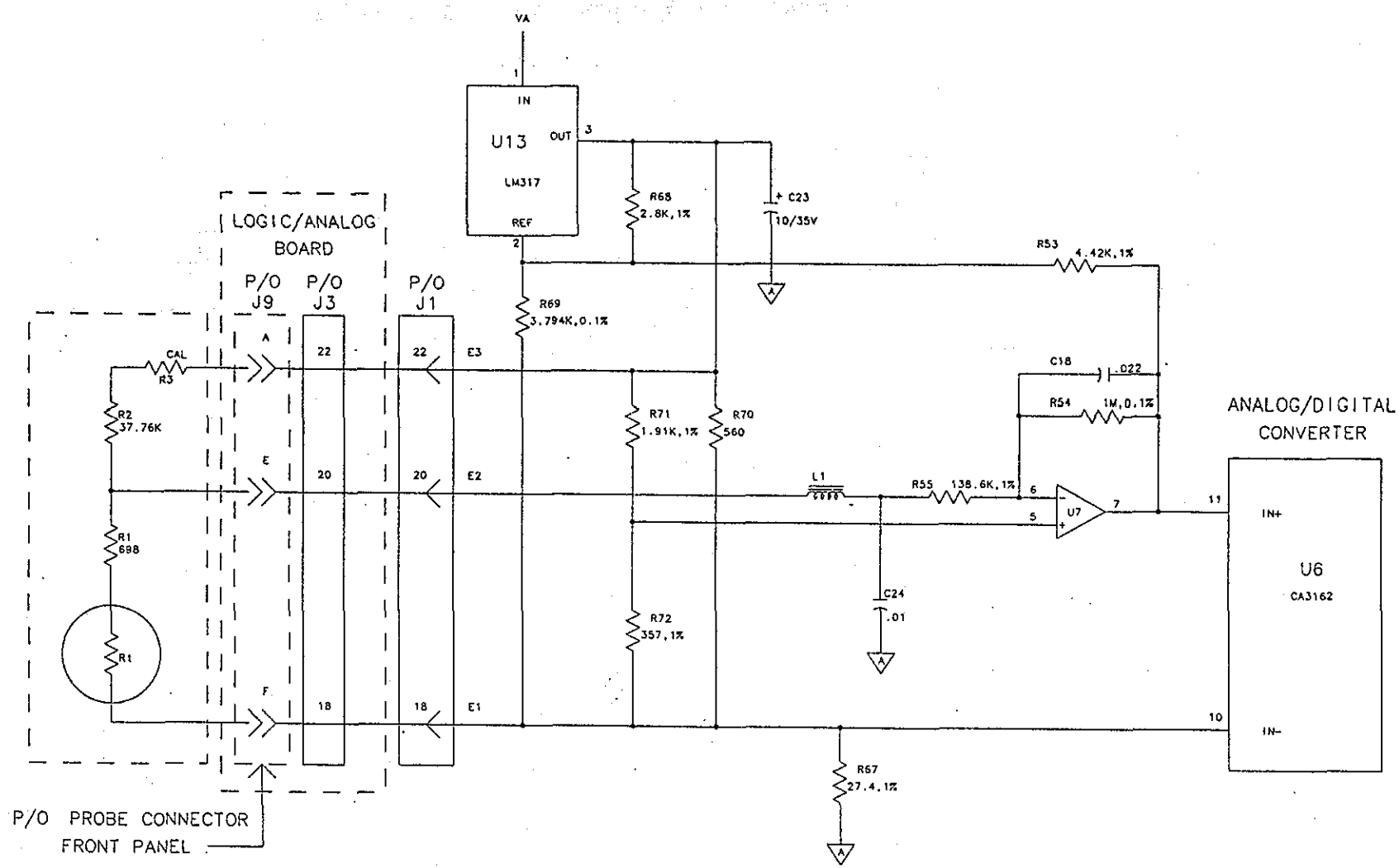

Figure 3-34. Analog Input and Linearizer

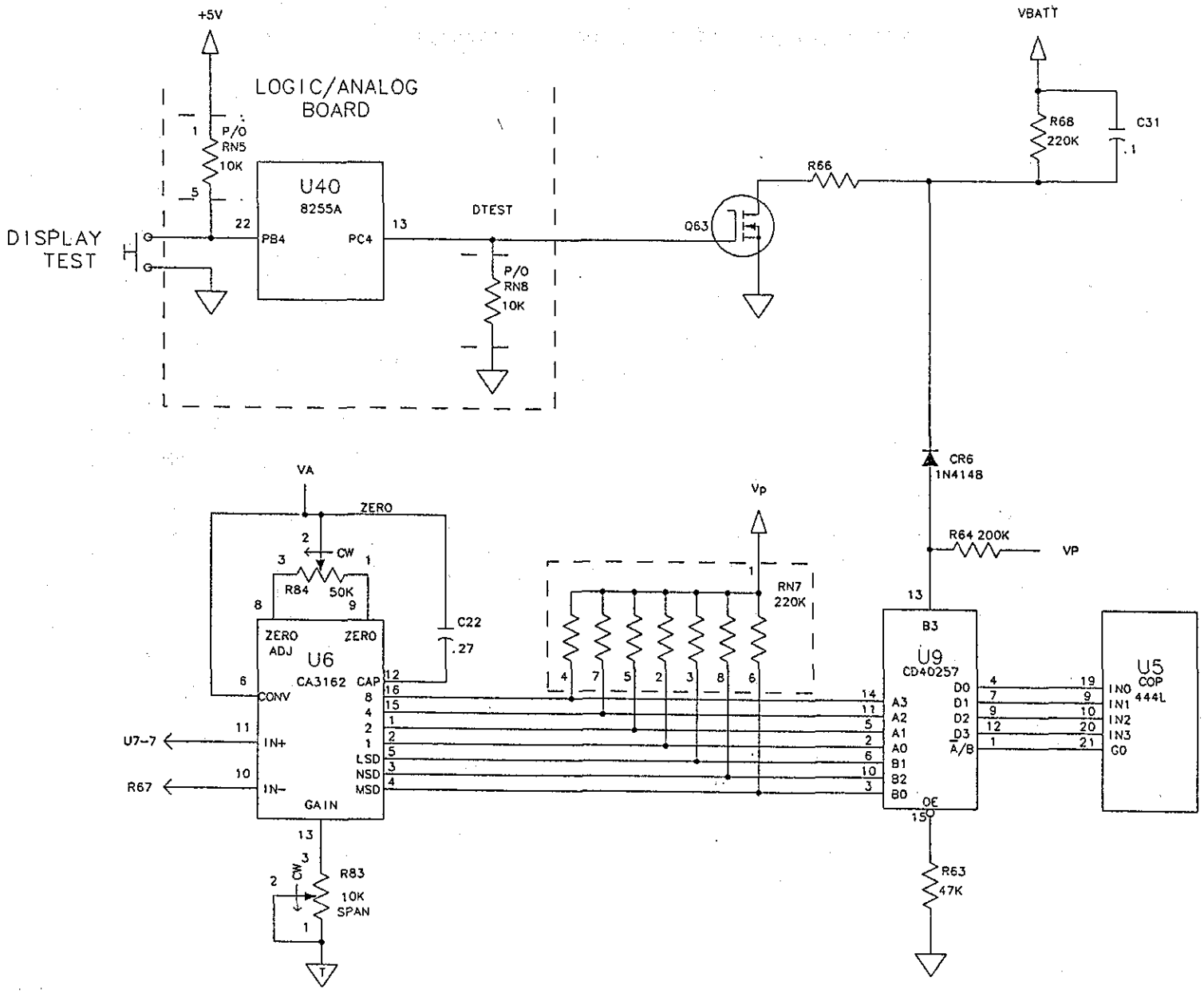

Figure 3-35. A/D Converter and Multiplexer

The zero adjust circuit of U6 ensures that when the input from the analog circuit is zero volts, the digital output of U6 is also zero. R84 (ZERO) is a variable resistor which can be manually adjusted.

The voltage level is coded in three four-bit data words at the 8, 4, 2, and 1 outputs of U6 (U6-16, 15, 1, and 2). Each four-bit word is equivalent to one raw digit of the temperature reading. Whether it is the ones (least significant digit [LSD]), the tens (next significant digit [NSD]), or the hundreds (most significant digit [MSD]), is indicated by the LSD, NSD, and MSD outputs of U6 (U6-5, 3, and 4).

The digits do not indicate the actual temperature, but represent the temperature data. For example, 000 represents 88.0°F and 999 represents 107.9°F, the top and bottom of the temperature range. Every value from 000 to 999 represents a temperature from 88.0°F to 107.9°F. The µcontroller converts this raw value to the actual temperature reading. The digits are output sequentially with the MSD, NSD, and LSD digit strobes, indicating which digit is present. U6 operates continuously at a rate of about 9.5 milliseconds per conversion.

3.10.5 Multiplexer (U9, figure 3-35)

The multiplexer accepts digital information from the A/D converter and display test signal. Output is to the µcontroller in the form of four-bit data words at D0-D3.

Inputs A0-A3 (U9-2, 5, 11, and 14) are temperature data. Inputs B0-B3 (U9-3, 6, 10, and 13) are digit strobes and the display test state. A0 receives data from the "1" output of U6; A1 from the "2" output; A2 from the "4" output; and A3 from the "8" output. B0 receives data from the MSD output of U6; B1 from the LSD output; B2 from the NSD output. B3 receives the display test state. A0-A3 and B0-B3 are two distinct four-bit words.

The multiplexer select (SEL), at U9-1, acts as a switch to pick which four-bit word, A or B, is sent to the µcontroller through outputs D0 through D3 (U9-4, 7, 9, and 12). The A word is selected when SEL is LO; the B word is selected when SEL is HI. SEL is controlled by the G0 output of the µcontroller (U5-21).

The OE input of the multiplexer (U9-15) is normally pulled down by R63. It can be driven HI by test equipment to put the multiplexer's outputs in a high-impedance state. This allows simulation of data to facilitate testing.

3.10.6 Display and Display Driver (figure 3-36)

µController outputs L7 and D0 through D3 are the display enable strobes. They send signals to the display indicating which display (DS10 through DS14) is to be illuminated. This output works in conjunction with the SK (decimal point) and L0 through L6 output which indicates to the display which segments (a through g) are illuminated for any one digit. Only one digit is illuminated at any given time, but the digits are turned on and off in succession 250 times per second. This gives the display the appearance of containing five digits which are illuminated constantly.

When L7 and D0 through D3 are driven HI one at a time, they cause Q64, Q48, Q54, Q60, or Q61, respectively, to conduct. These transistors sink current from the display cathodes. L0 through L6 and SK drive segments g through a and the decimal point, respectively, through buffers Q41 and Q40, Q42 and Q39, Q33 and Q47, Q34 and Q46, Q29 and Q53, Q30 and Q52, Q23 and Q59, and Q24 and Q58. The signals from L0 through L6 are sent to all five displays simultaneously. The display for which the data is valid is enabled (strobed) by the appropriate display enable strobes, L7 and D0 through D3. (The decimal point is only connected at DS12.)

3.10.7 Watchdog Circuit (figure 3-37)

The watchdog circuit turns the thermometer off if there is a µcontroller malfunction causing a loss of the digit strobes. The watchdog circuit constantly receives signals from the displays through Q54 and Q60 and Q61 if the S2 internal DIP switch no. 5 (°F/°C) or the NORMAL/MONITOR mode switch are closed (MONITOR or °C selected). Under normal conditions, C21 remains discharged by Q51 and yields a high input at U8 pins 4 and 5. However, if a malfunction occurs and no signal is received at U8 pins 11, 12, and 13, C21 charges through R57. The resulting LO signal is received at U8 pins 4 and 5, resetting the latch and turning off the display/thermometer board.

3.10.8 Normal/Monitor Modes (figure 3-37)

a. Normal Mode

Setting the NORMAL/MONITOR mode switch to normal mode causes the µcontroller to use a different program than that used in the monitor mode. Temperature is estimated in about 30 seconds based on the rate of change of the resistivity in the probe. The predicted value is reported to the display.

b. Monitor Mode

Setting the NORMAL/MONITOR mode switch to monitor mode causes the µcontroller to use a different program than that used in the normal mode. Temperature in the probe is allowed to equilibriate and is continuously monitored and updated to the display. The µcontroller detects the state of the NORMAL/MONITOR mode switch through input SI via U8-10.

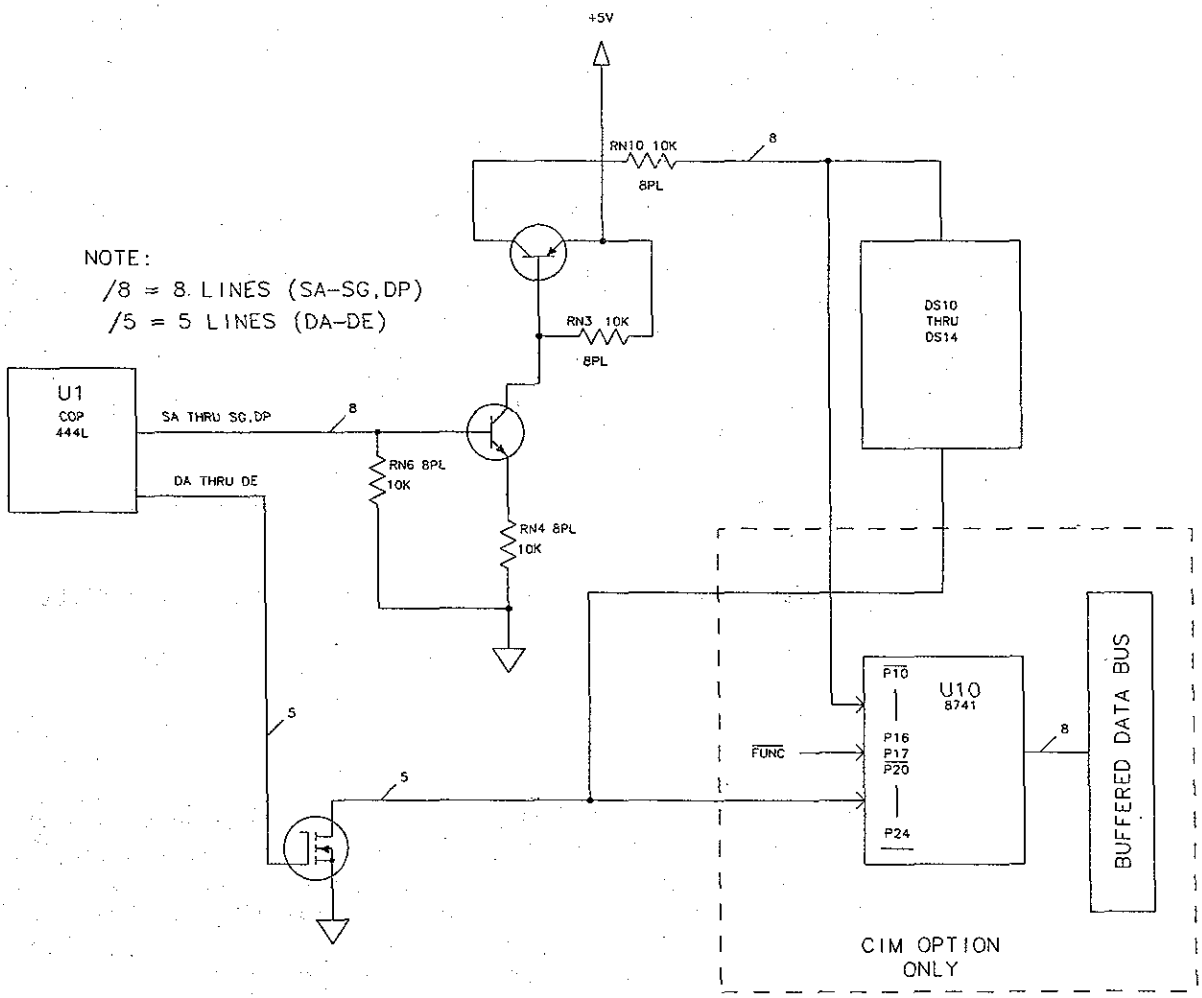

Figure 3-36. Temperature Display and Display Driver

3.10.9 S2 Internal DIP Switch No. 5 (°F/°C) (figure 3-37)

Setting the °F/°C DIP switch to °C (Centigrade) or °F (Fahrenheit) causes the µcontroller to use different constants to calculate the temperature. The µcontroller detects the state of the switch through input SI via functional signal from U8-10.

The S2 internal DIP switch (no.5) is accessible through louver holes in the bottom, right-hand side of the instrument (°F = up position; °C = down position).

3.10.10 Power Control Circuit (figure 3-38)

The power control circuit consists of Q37, Q38, Q45, and U8.

Power enters the thermometer at J1-24. J1-24 is connected to +5V supply by plugging in a thermometer probe or tester.

The CPU turns the thermometer module on and off by controlling the power control circuit. The CPU monitors the thermometer probe well to determine when to power-up the thermometer board. When the temperature probe is plugged in but out of its well (i.e., the probe sense optics are turned on) the TEMP signal (U40 pin 12) from the CPU goes HI. (See table 3-7.)

Table 3-7. CPU Monitoring of Thermometer Probe Well

Condition	CPU signal	Q57 Drain
Probe not in well:	TEMP = HI	LO
Probe in well:	TEMP = LO	HI

R/S flip-flop U8, pin 9, applies power through Q38 and Q45. When U4 pin 9 goes HI, power flows to ground through Q37, saturating Q38 and Q45. Q38 supplies power (VA) to the analog input and linearizer (U7) and A/D converter (U6). Q45 supplies power (VP) to the multiplexer (U9) and µcontroller. +5THERM is always present when the probe connector is plugged in, and supplies power to U8.

Depending on the position of the thermometer probe, there are two methods for activating the thermometer:

a. By removing the probe from the storage well when initially both the connector and probe are in place (i.e., Q57 drain HI and the thermometer is off). In this case, removal of the probe causes the CPU to pull Q57 drain to ground. This HI to LO transition is coupled through C27, setting flip-flop U8-9 HI and activating the thermometer.

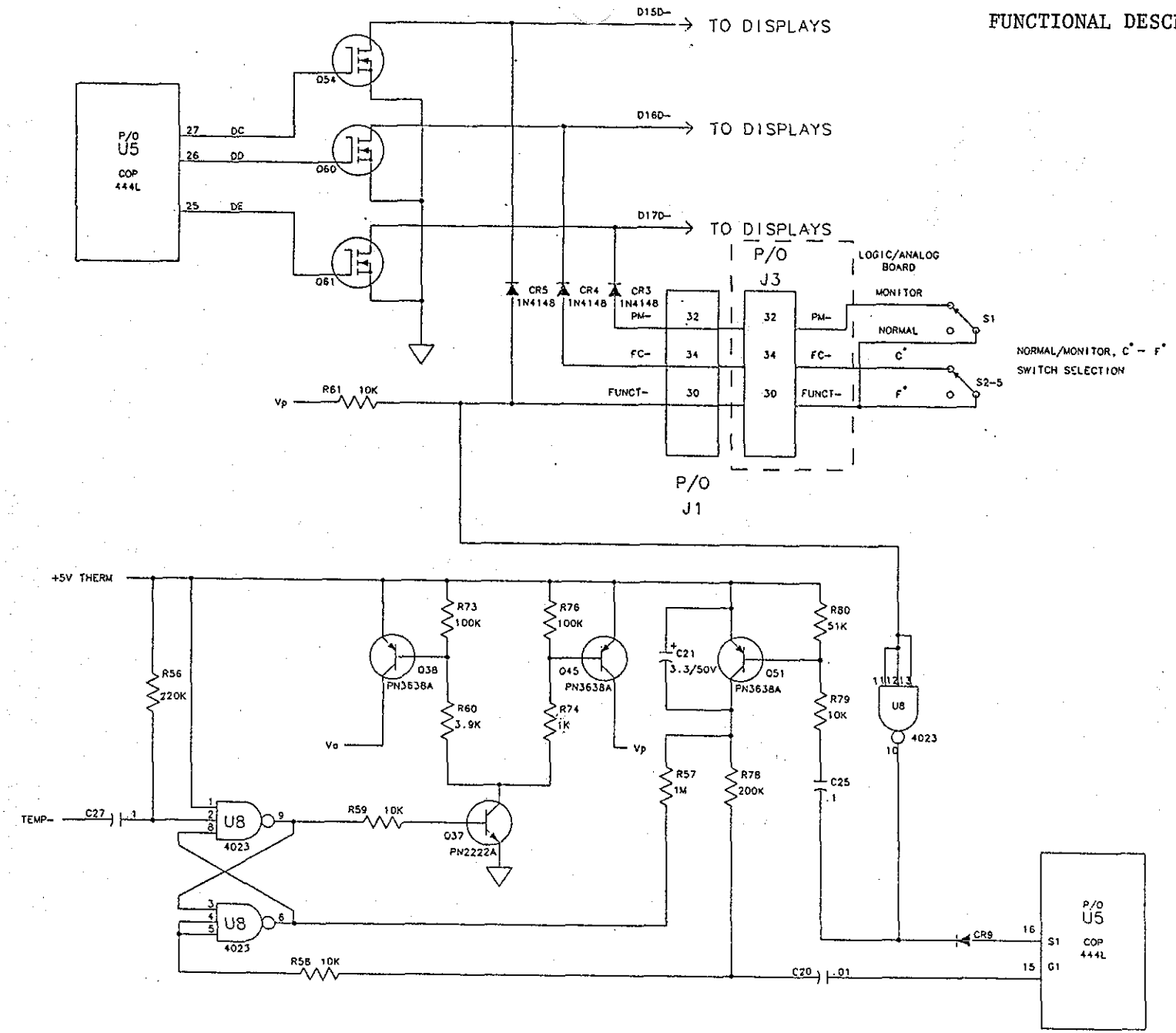

Figure 3-37. Watchdog, Normal/Monitor, and °F/°C Selector Circuits

b. By inserting the probe connector when the probe storage well is empty (i.e., Q57 drain LO). In this case, +5V charges C27 through R56, and U8 pin 2 is held LO until C27 charges to a HI level. This delay causes U8 pin 9 to become HI, activating the thermometer.

Application of power from Q45 initializes the µcontroller. When power is first applied, VP goes HI and RST is LO. Charging C8 through R14 delays the rise of RST to logical 1, allowing initialization to occur.

The thermometer can be deactivated by removing the probe connector. Alternatively, inserting the probe into the probe storage well causes the µcontroller to output a LO to U8 pins 4 and 5, causing U8-9 to flip to LO. The µcontroller senses the inserted probe condition through CR7 and CR8 via its G2 port.

3.11 CIM EQUIPPED MODEL 4200C

The CIM equipped Model 4200C contains three additional functional blocks. These blocks are designed to permit ASCII monitoring of the instrument through an RS-232 port.

The blocks are an IVAC CIM II board, a real-time clock, and a thermometer display interface port.

3.11.1 CIM Interface (figure 3-39)

The CIM equipped Model 4200C incorporates an IVAC CIM II board which contains a UART, baud rate generator, and RS232 level converters to interface to an external data gathering system. The CIM II board is interfaced to the 4200C through J4. This 16-pin dedicated connector is in parallel with the test connector J5, but carries only the signals and power required by the CIM II board.

U16 is a bi-directional buffer used to isolate the CIM board loading from the data bus. It is enabled by EXTIO- (external I/O access), and the data direction is determined by RD-. RN2 maintains a HI to avoid ambiguous logic levels on the external bus IOD0-IOD7 when U16 is not enabled.

The address lines IOA0 and IOA1 are buffered ADDR8 and ADDR9. (The upper eight address lines copy the lower eight address lines during an IO transfer.)

The read or write command to the CIM board is derived and buffered from the S1 status line from the CPU as IOWR-. LO is a write operation and HI is a read operation.

The CIM board is selected for an I/O operation when IOXSEL- is LO. It's timing is derived from the address decoder output EXTIO- and WR- or RD-.

+5 Volts and +12 volts are provided at J4 to operate the CIM board.

3.11.2 Thermometer Display Interface Circuit (figure 3-40)

The thermometer interface (U10) is an 8741A satellite processor on the display/thermometer board. It contains 1K byte of program ROM and 64 bytes of RAM. It decodes temperature display segment and digit driver signals and thermometer control signals. These signals are processed to convert the display information to an 8-bit status code and four-digit BCD code for transmittal to the CPU. The interface is required because the multiplexed temperature display is not compatible with the CPU data bus and CPU's timing.

The thermometer interface interprets all possible conditions that can occur with the thermometer, as well as the contents of the temperature display.

The thermometer display interface is clocked by the buffered 3 MHz clock signal (BCLK) from the CPU via U12, pin 6 and 4. Power-on reset (BRESET) from the CPU is inverted to initialize the thermometer display interface.

U10 ports P10-16 and P20-24 serve as input ports for the temperature display segment and digit strobe signals, respectively. T0, P25 and P26 monitor thermometer power status and P17 monitors the NORMAL/MONITOR switch and the S2 internal DIP switch settings (nos. 1-6).

U11 functions as a pulse stretcher monitoring the temperature display decimal point (BDP), because the decimal point is intermittently clocked at the thermometer μcontroller's clock rate (62.5 kHz).

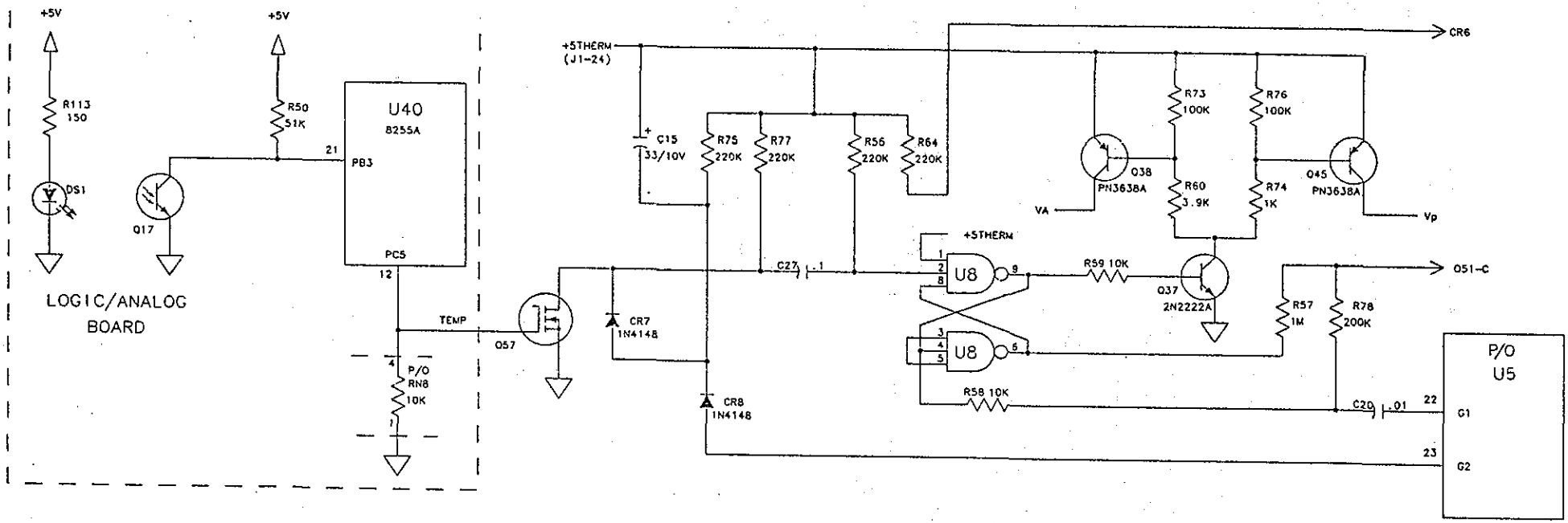

Figure 3-38. Thermometer Power Supply and Control Circuit

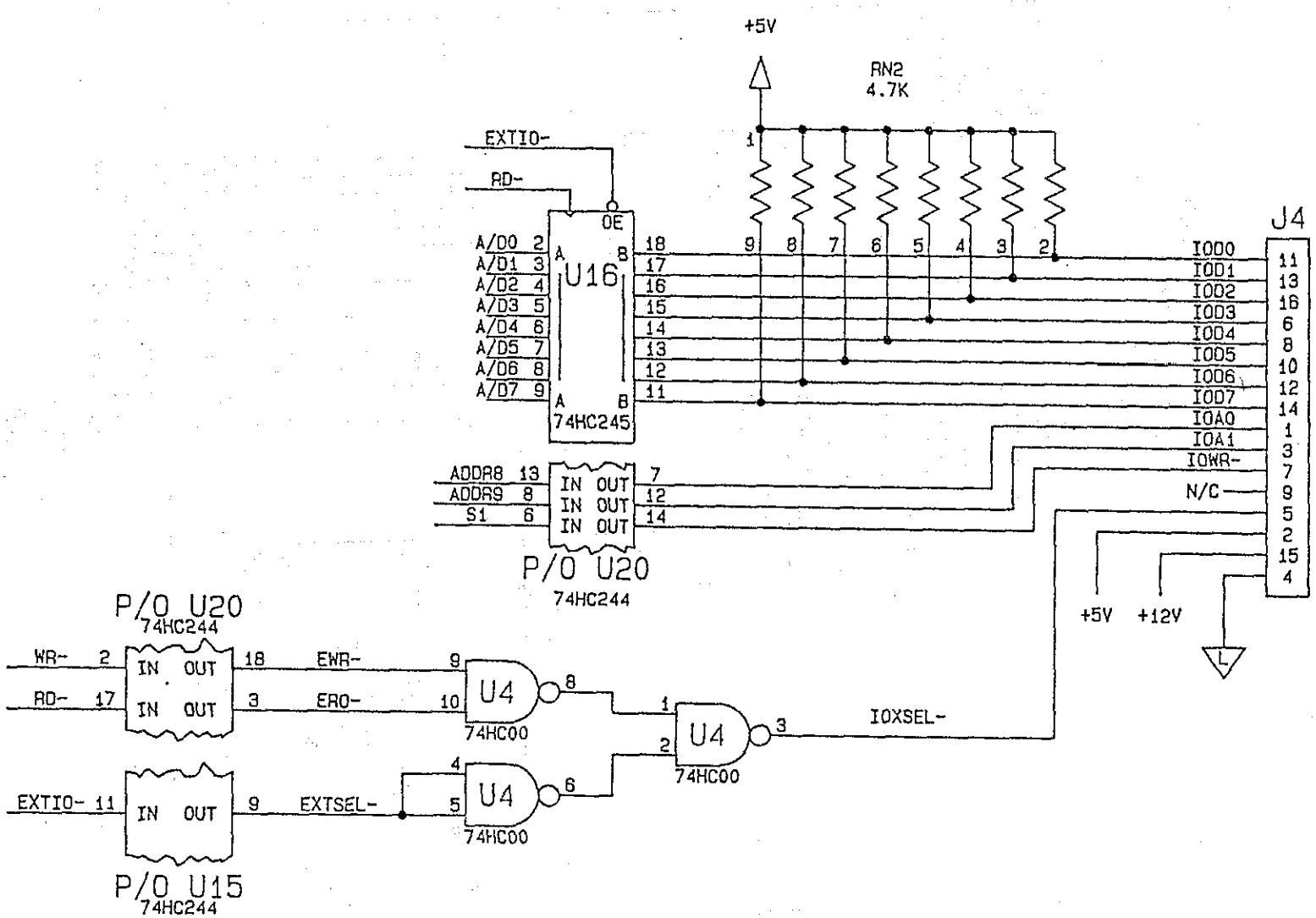

Figure 3-39. CIM Interface

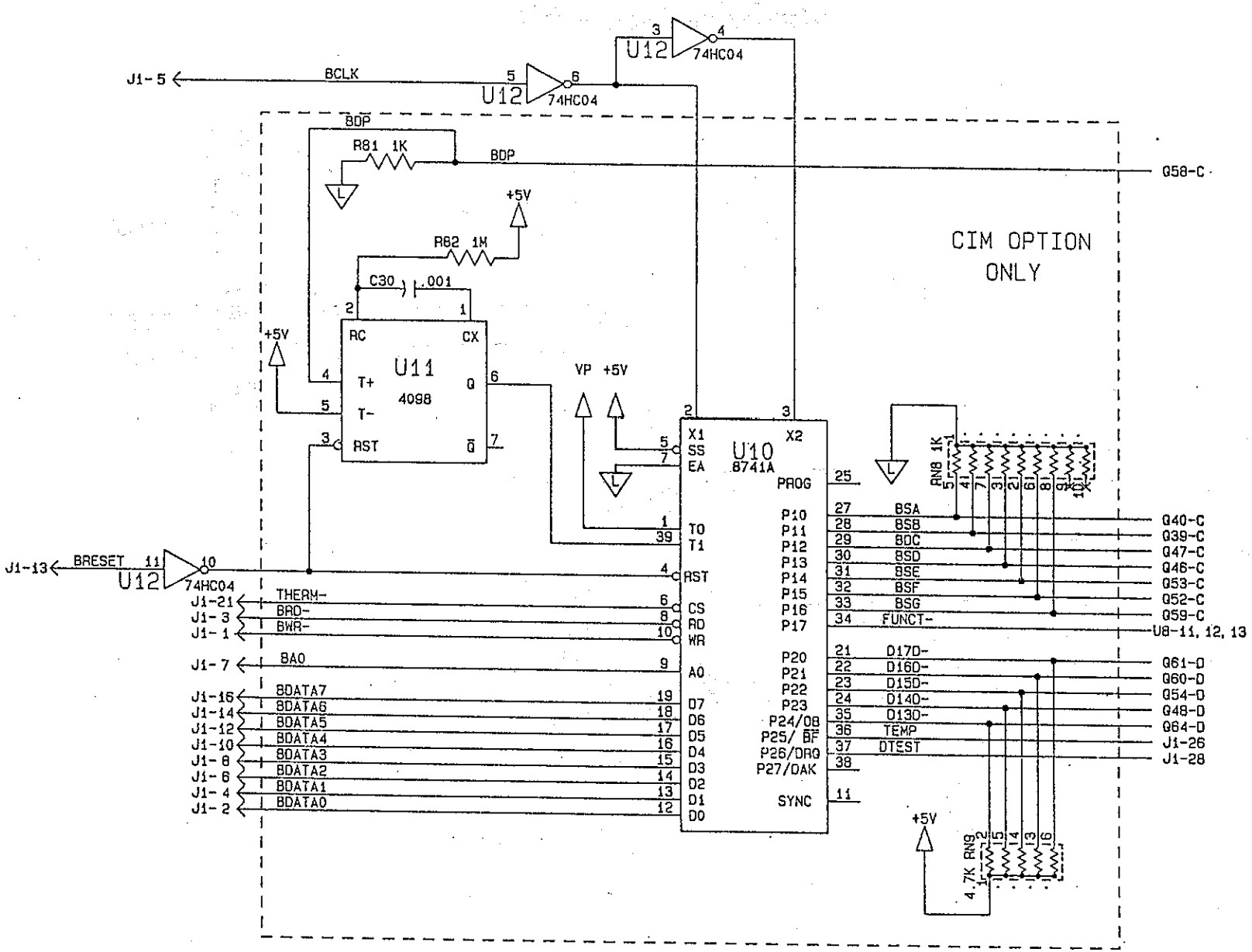

Figure 3-40. Thermometer Display Interface

3.11.3 Real-Time Clock (CIM Option only, figure 3-41)

The real-time clock, U29 on the logic/analog board, is included in the CIM equipped instrument for providing time and date of measurements to external devices, such as printers. A 32.768 kHz oscillator is the time base (Y2). U29, Y2, and also U33 are powered by the +5VAO (+5 volts always-on) from the power regulator board so that the clock continues to function with the instrument turned off. U33 is a power-off detection circuit which disconnects the chip-enable (CS) of U29 from the address decoder to prevent disruption of the time-keeping and RAM data during instrument power down. A signal PWRON from the power regulator board goes LO at power-down time before the +5 volt logic supply is removed. This is inverted by U28D. The inverted PWRON sets R/S flip-flop U33-4 and U33-10 with pin 4 LO, turning off Q5 which disconnects the active low CS of U29 from the address decoder U5-9. CS is then pulled HI through R52, keeping U29 disconnected from the bus. U33-11 prevents the R/S flip-flop from setting during a time when CS is LO, delaying the disconnect process until U29 is not being accessed. When the instrument is turned on, the CPU reset (RESET) goes high for a predetermined period at U33 pin 1. While RESET is HI, C56 charges through R53 until U33 pin 2 is HI, delaying reset and causing pin 3 to go LO, resetting RS flip-flop U33-4 and U33-10. Pin 4 then goes HI, turning on Q5, connecting U29 to the address decoder U5-9. U29 uses the multiplexed feature of the data bus to derive both address and data from the processor, using the ALE control line. Network R14 and C33 delays the initial application of +5VAO to U29 pin 22 to set an internal power fail software flag in U29 when power is applied to the instrument for the first time.

U33-4 also provides the power status signal PWR_GOOD to U31 and U32.

3.12 SOFTWARE

This instrument contains two entirely separate programs, one for the thermometer and one for the blood pressure monitor. The thermometer program resides in 2 KB x 8 of ROM which is located inside the COP444L µcontroller. The blood pressure monitor program resides in one 32 KB x 8 EPROM and is executed by an 80C85 CPU.

3.12.1 Thermometer Program

The thermometer program is a noninterrupt-driven program that performs tasks based on the settings of the DISPLAY TEST switch, the S2 internal DIP switch no. 5 (°F/°C), and the NORMAL/MONITOR mode switch, and on the internal probe detect optics (activated by removing the probe from or replacing it into the storage well on the front of the instrument). A description of the program operation and features is integrated with the electronics description of the thermometer (see section 3.10).

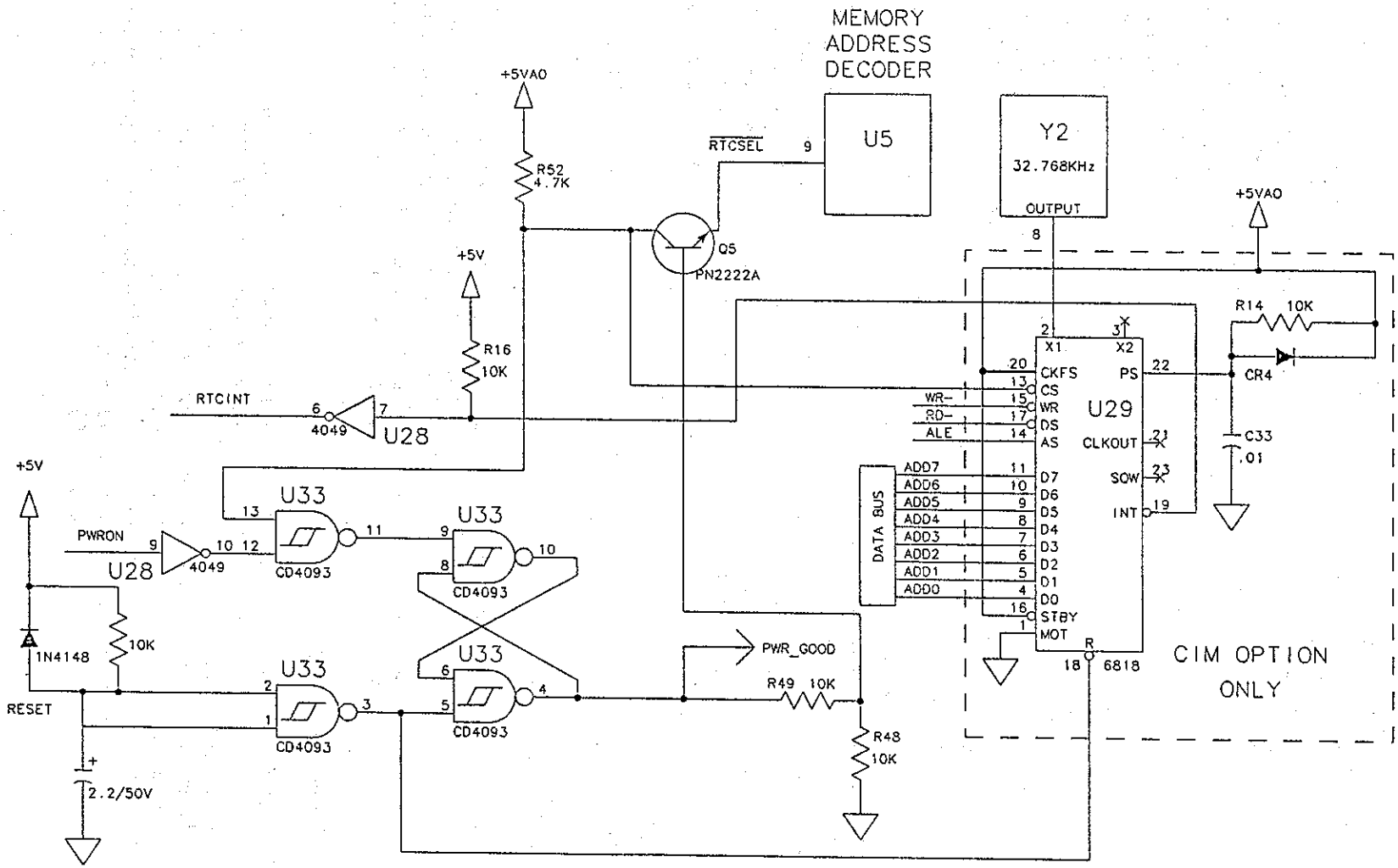

Figure 3-41. Real-Time Clock

3.12.2 Blood Pressure Program

The blood pressure monitor program is organized into modules that are linked together at load time. Three modules and a segment of another module perform interrupt processing tasks. The remainder perform the following tasks:

a. Cuff inflation or pump-up

b. Deflate

c. Compute blood pressure

d. Calibrate

e. Offline display test

f. Diagnostic tests

g. Redisplay values (memory mode)

Figures 3-42 through 3-44 depict program operation. The main program flow is shown in figure 3-42. Flowcharts (figures 3-43 and 3-44) show how the two interrupts are processed. The two interrupts are the START/RESET switch and the time base interrupt, occurring about every 683 microseconds. The real-time clock is a third interrupt.

When power is first applied, software diagnostics of memory and failsafe hardware are executed. If a malfunction is detected at this time, the program will display a FIX ME message and halt. Upon completing the diagnostics, the program initializes various timers and other data values and finally enters a wait loop. The program exits the wait loop to start a blood pressure measurement when the auto-start condition is detected or when the START/RESET interrupt occurs. While in the wait loop, the program checks that the pump motor is off and that the cuff pressure does not exceed 20 mmHg for longer than 20 seconds. If either test fails, the instrument will display a FIX ME message. Also during wait, it tests the internal switches to see if the calibrate mode has been selected.

When a blood pressure measurement has been requested, the program enters the inflate cycle. When inflation is complete, the deflate and data-taking cycle is entered. Finally, the program computes the blood pressure and returns to the wait loop.

The START/RESET interrupt program (figure 3-43) determines what function the operator has requested and responds accordingly. The program does not return control to the interrupted location. Instead, it passes control to the main program at the location shown. The START/RESET interrupt can be disabled; it is disabled, for example, during memory mode. In memory mode, the program polls (or monitors) the state of the START/RESET switch instead of using the interrupt.

The time-base interrupt program executes one of several branches each time the interrupt occurs (see figure 3-44). The program is organized so that each branch is executed periodically. For example, the microphone signal is sampled and processed every two milliseconds. When execution of a branch is completed, control returns to the interrupted program unless a failsafe error condition is detected. The time base interrupt is disabled when the instrument offline display test is being executed, and at power-on when the diagnostics are performed.

3.12.3 Hardware Checks

The computer program tests the instrument's hardware for unsafe conditions, initially at power-on and periodically. If such a condition is detected, the instrument beeps audibly five times and displays a FIX ME x message (where x is a number or letter identifying the type of problem found). The values for x and their meanings appear in chapter 5.0. The computer program halts after displaying the message and can only be restarted by cycling the power switch on and off. Tests for FIX ME conditions 0, 2, and A through K (also W, X, Y and Z for CIM equipped instruments) are run only once each time power is applied; tests for conditions 4, 5, and L to N are performed periodically.

Tests corresponding to messages A through N are executed by comparing the value of the failsafe input port, FAIL1, with an expected value. The failsafe output port, FAIL0, is used to simulate conditions for tests corresponding to messages D through K. Both the expected input code and the output code (where appropriate) are listed in table 5-1. Table 5-2 summarizes the meanings of the bits on the failsafe input and output ports.

When the comparison test is made, failsafe input bits 0 through 6 must match the expected input code (failsafe bit 7 is not used and is masked by the software). If they do not match, the program displays the FIX ME message for the particular test being run and outputs to the PULSE display, in octal representation, the actual value of the failsafe input port.

Example: Pulse display 041 with FIX ME D.

	FSDIS / FSDUMP		FSMOT	FSCOMP / FS2	FS1	FS0
Binary	0	1	0	0	0	1
Octal	0	4			1	

Then compare with tables 5-1 and 5-2 to determine the faulty signal. The good signal corresponds to a 061 code. Therefore, there is a problem with the motor or motor detect circuitry in this case. The motor was detectd as being on when the motor should be off (a "1").

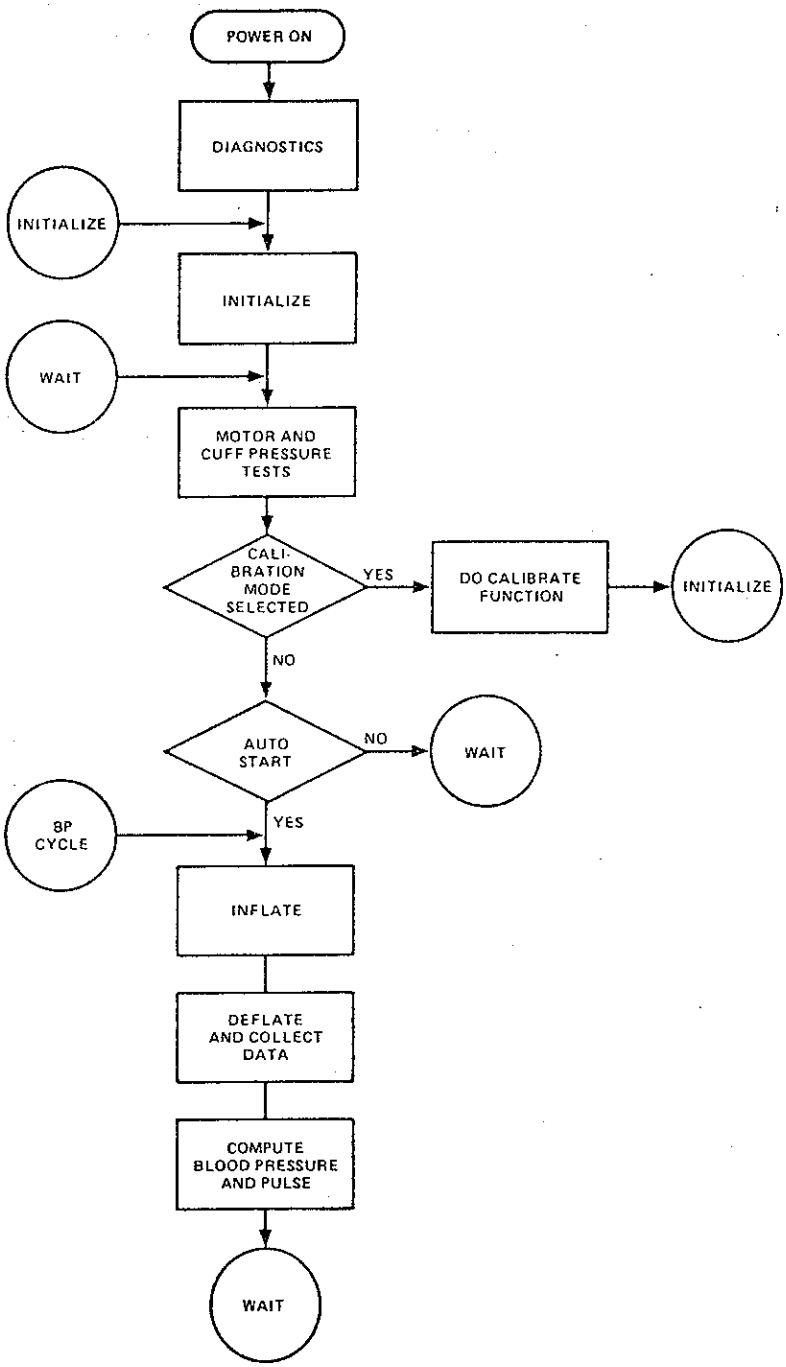

Figure 3-42. Main Program Flowchart

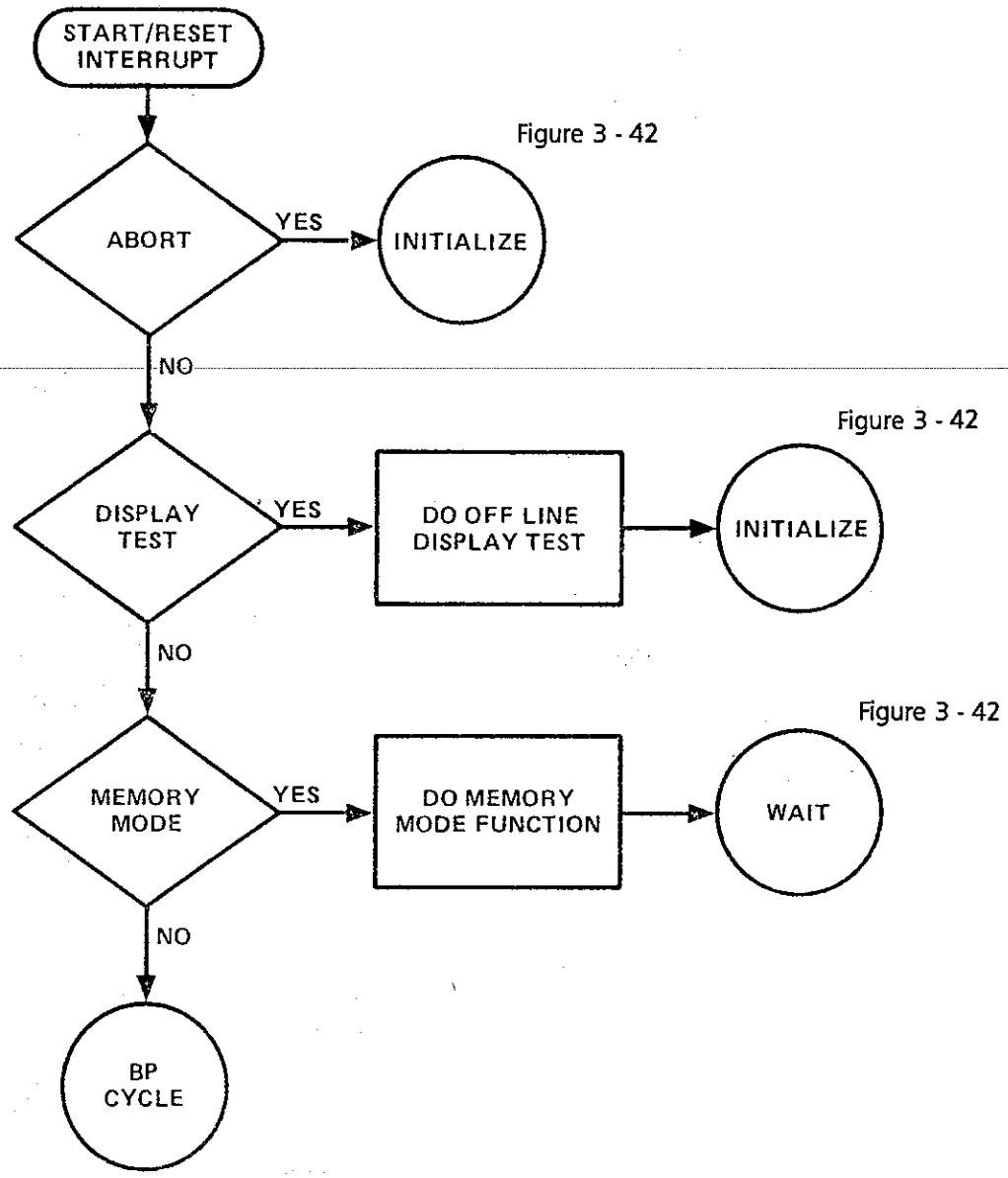

Figure 3-43. START/RESET Interrupts

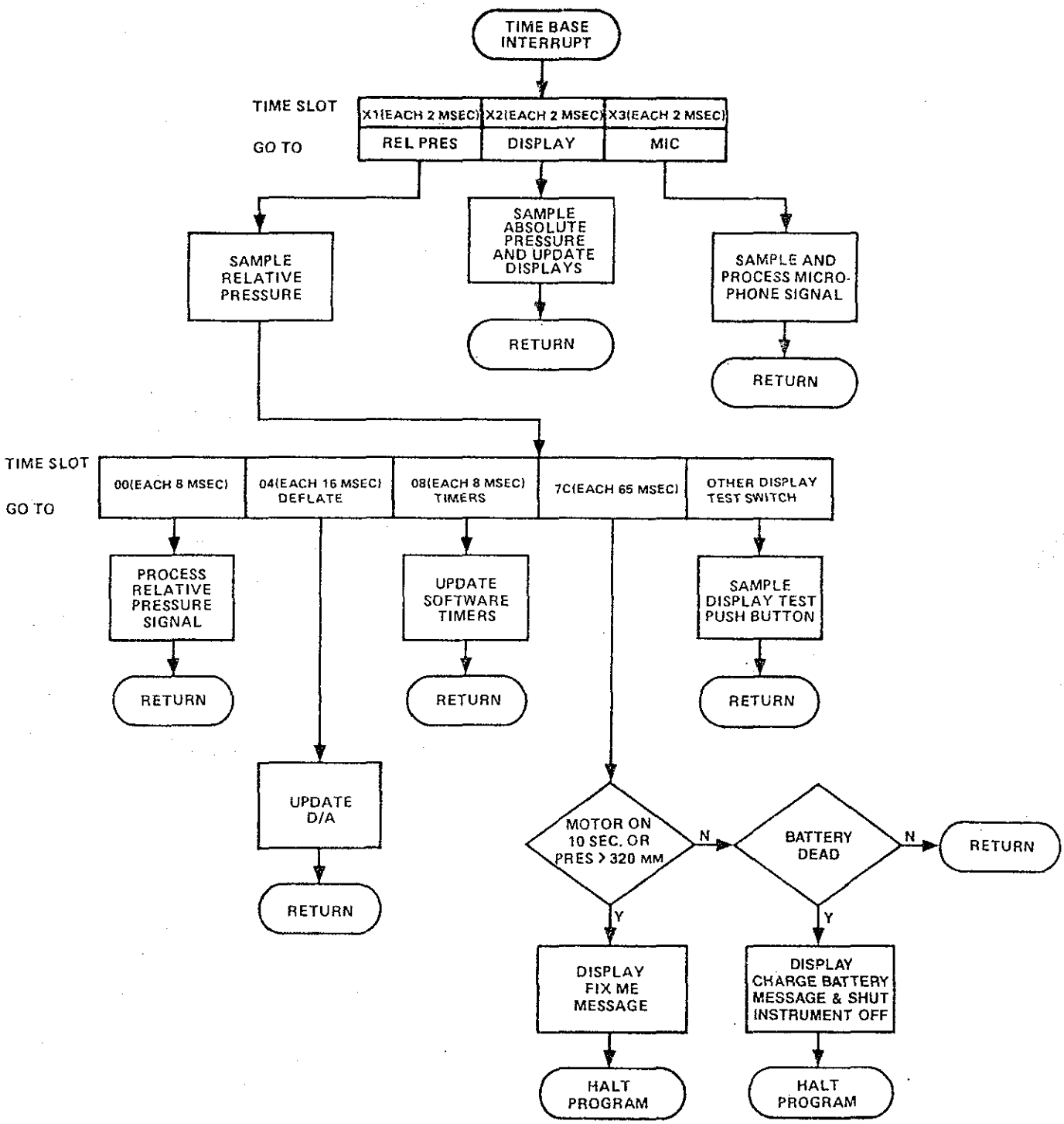

Figure 3-44. Time Base Interrupts

CHAPTER FOUR - SCHEMATICS

1.0 INTRODUCTION

This chapter contains the schematic diagrams that depict the detailed system operation of the VITAL•CHECK instrument - Model 4200. For specific schematic partial/block diagrams, refer to Chapter Three, FUNCTIONAL DESCRIPTION, of this manual.

NOTE: Schematics included in this manual represent the original issue of the printed circuit boards, and may not reflect future board revisions.

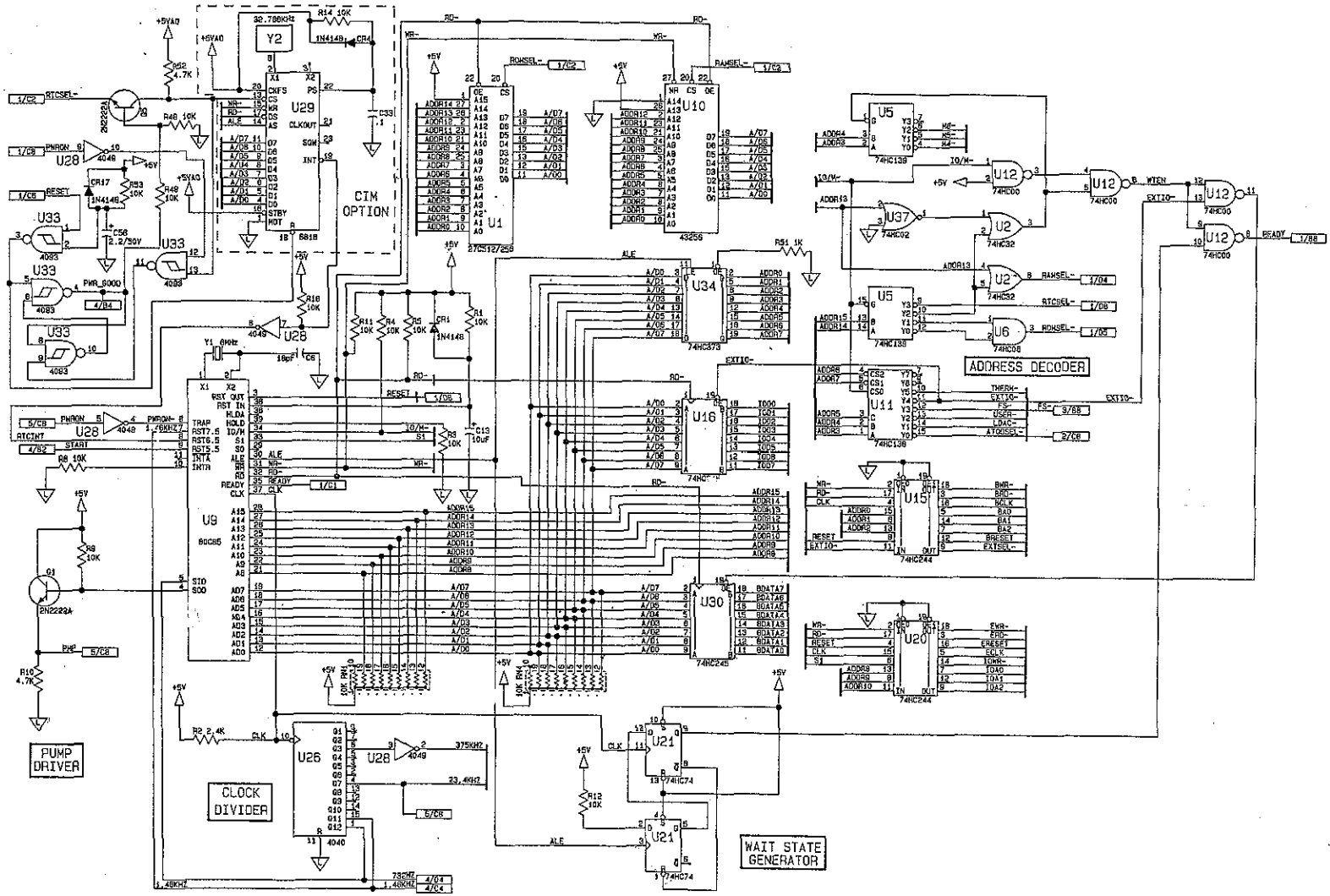

Figure 4-1. Logic/Analog Board
(sheet 1 of 6)

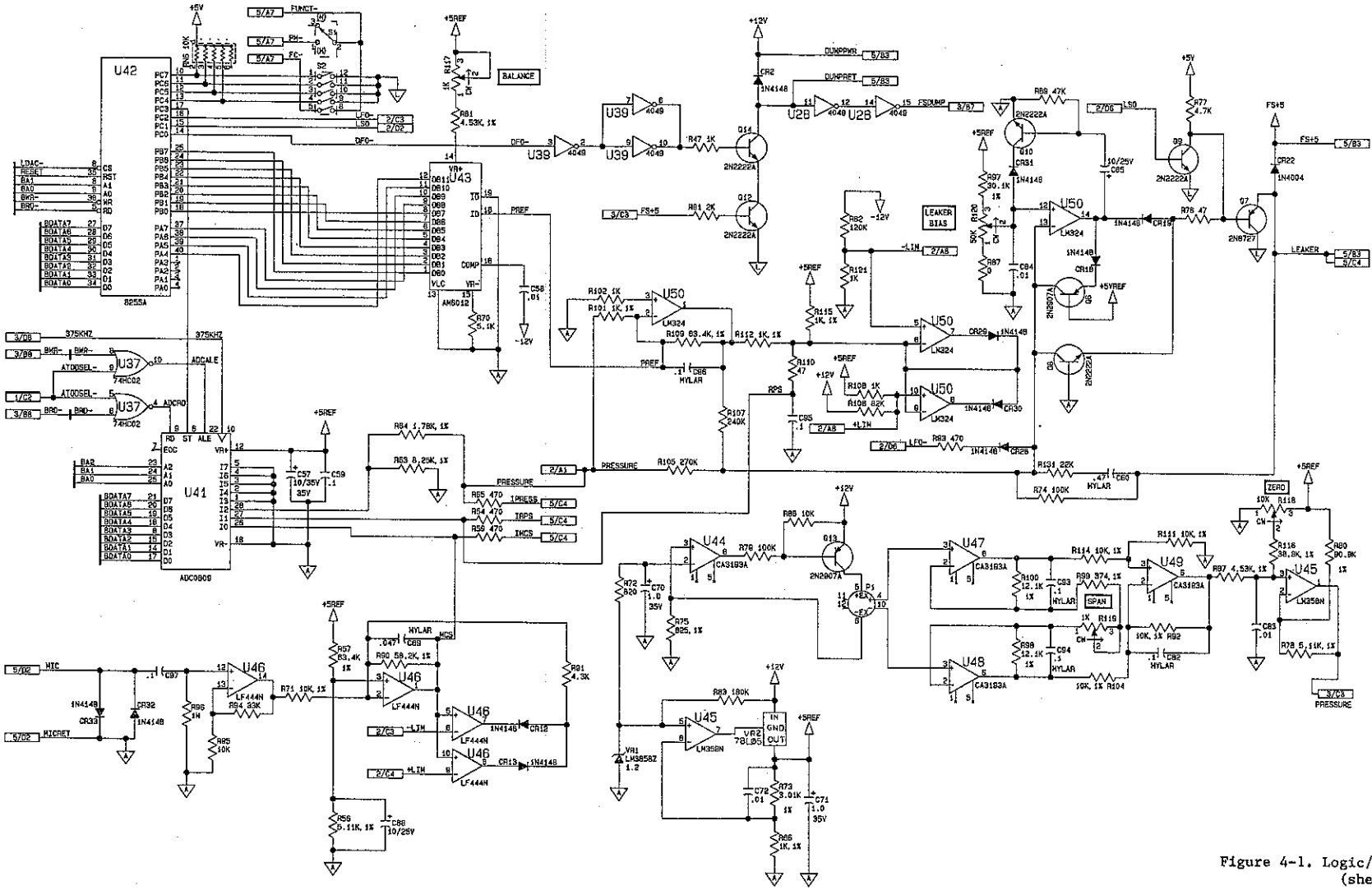

Figure 4-1. Logic/Analog Board
(sheet 2 of 6)

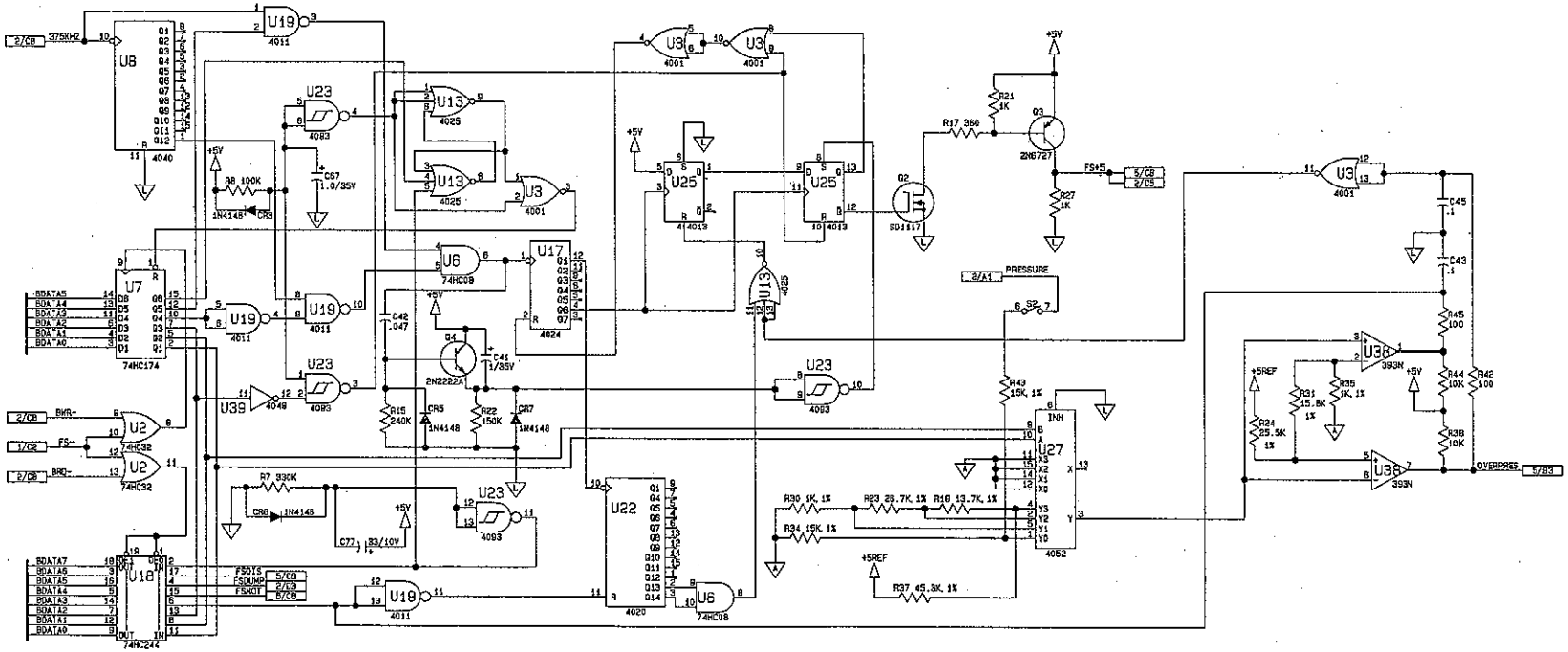

Figure 4-1. Logic/Analog Board
(sheet 3 of 6)

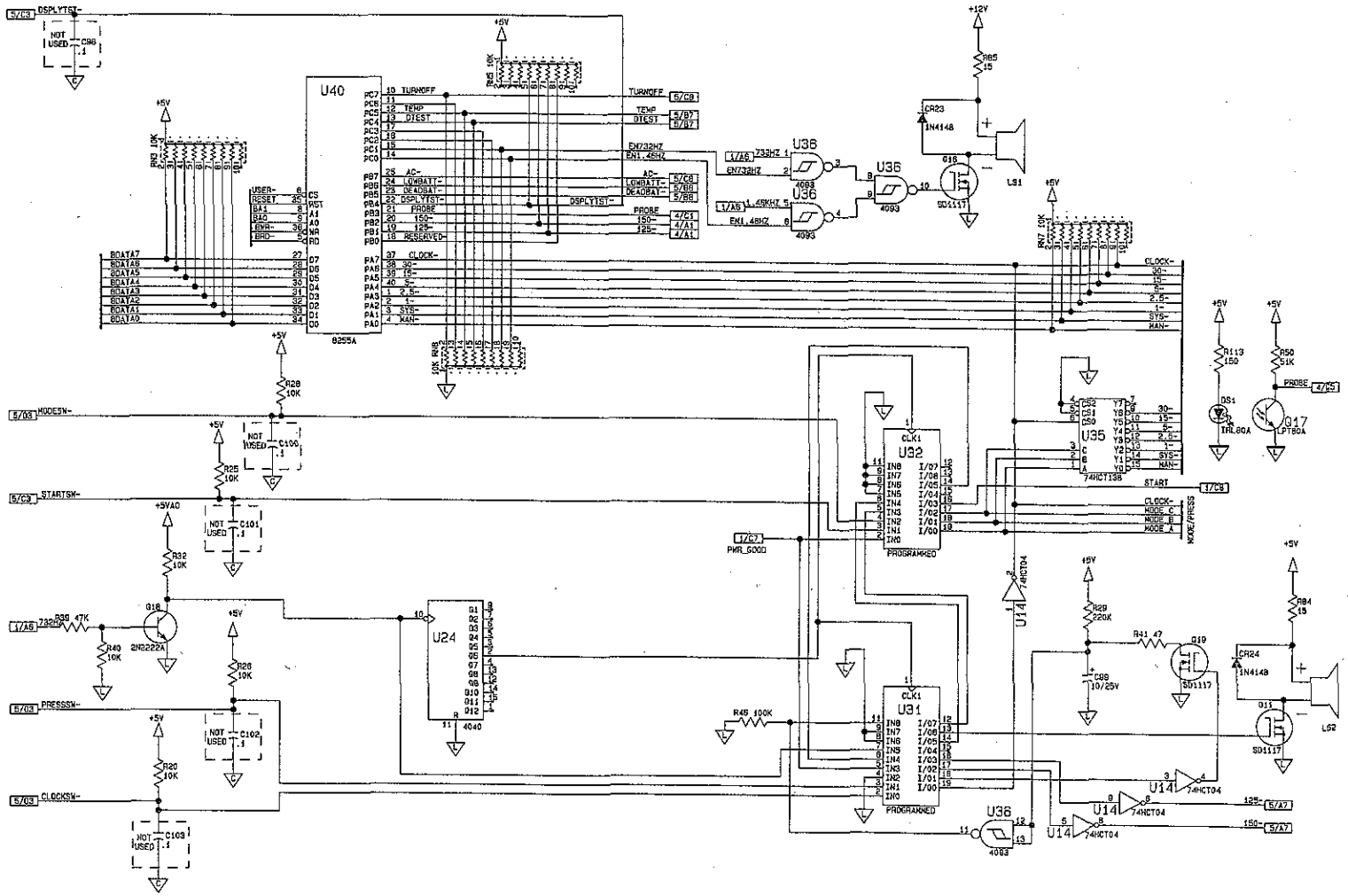

Figure 4-1. Logic/Analog Board
(sheet 4 of 6)

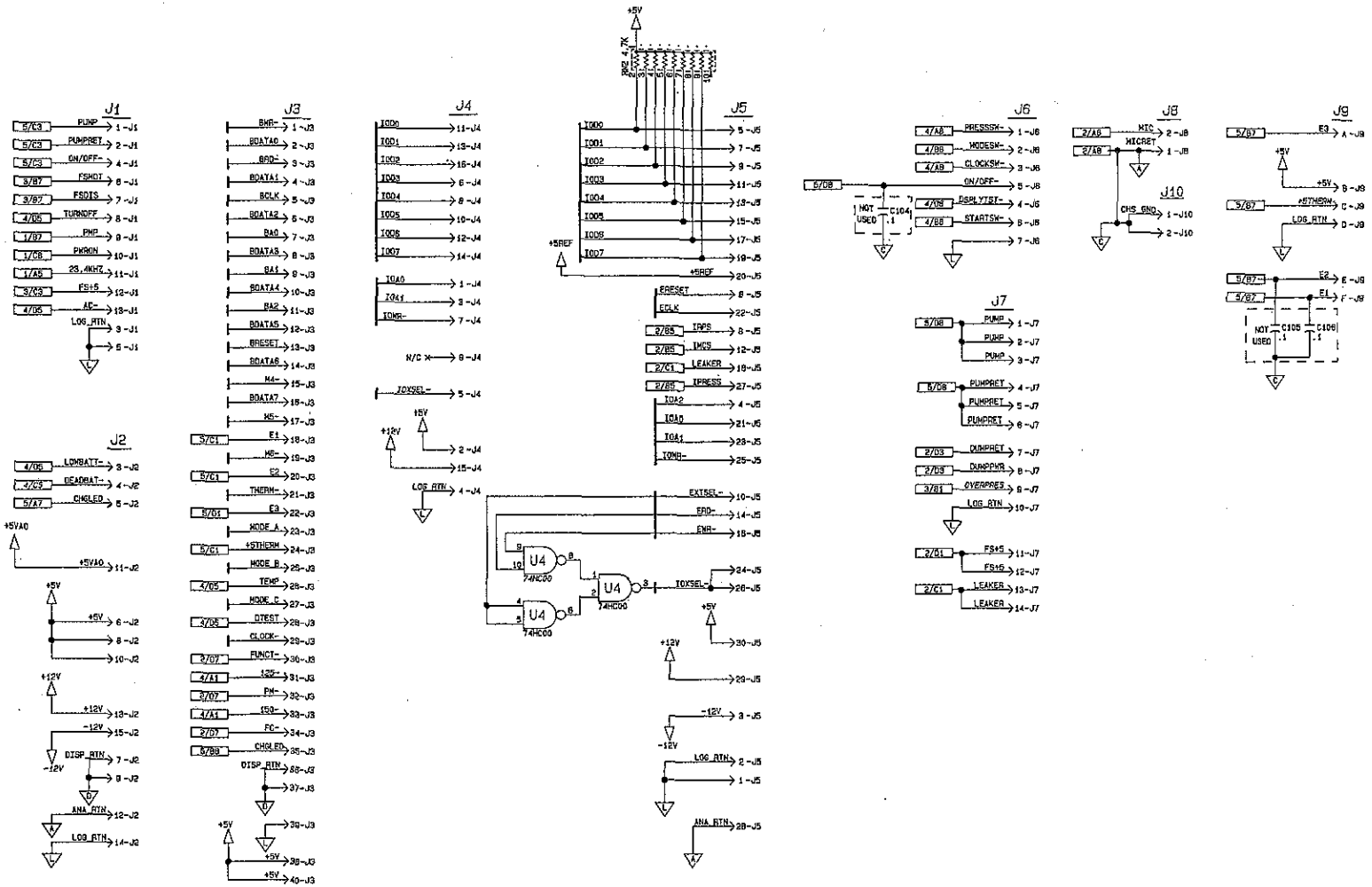

Figure 4-1. Logic/Analog Board
(sheet 5 of 6)

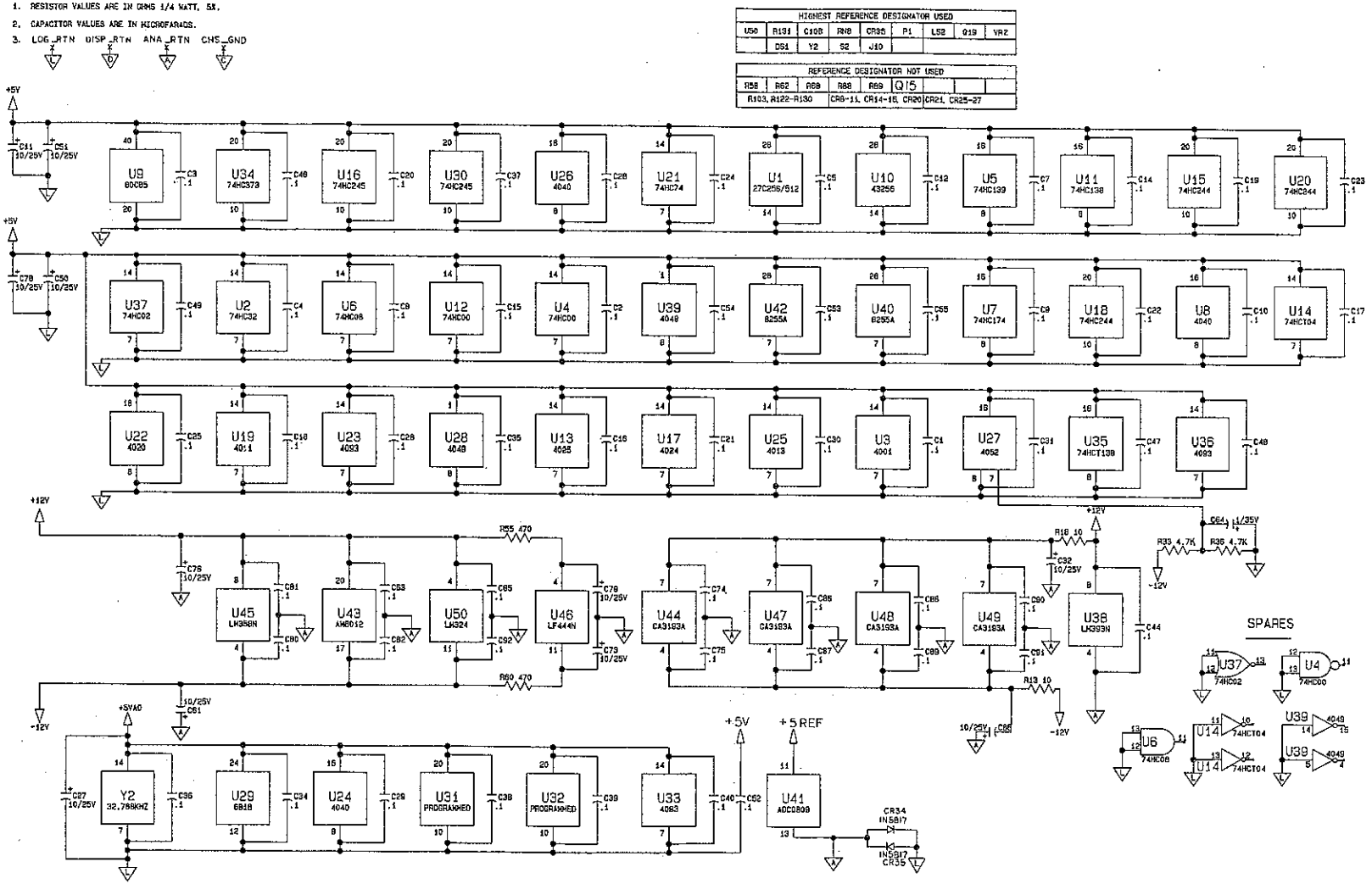

Figure 4-1. Logic/Analog Board
(sheet 6 of 6)

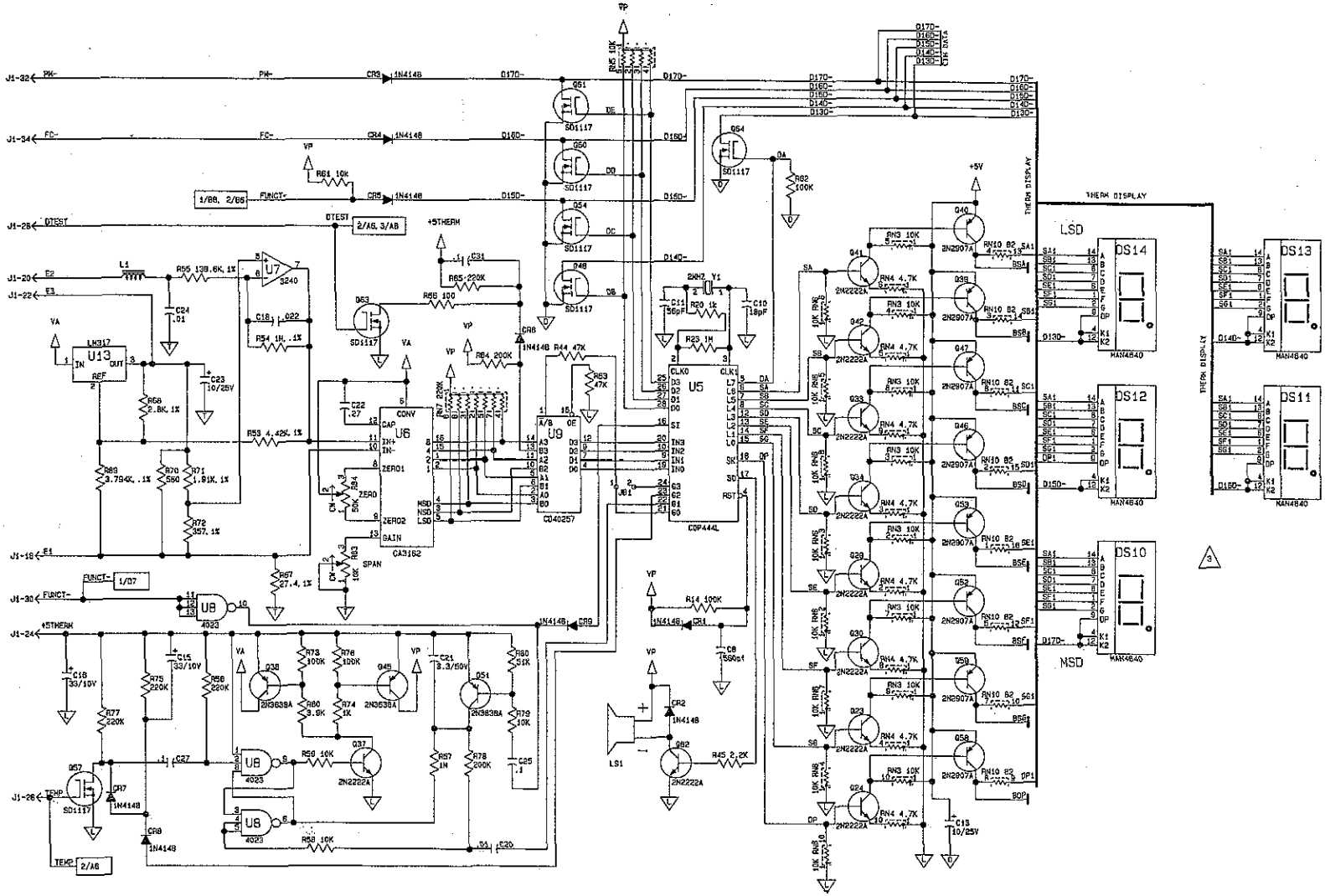

Figure 4-2. Display/Thermometer Board
(sheet 1 of 4)

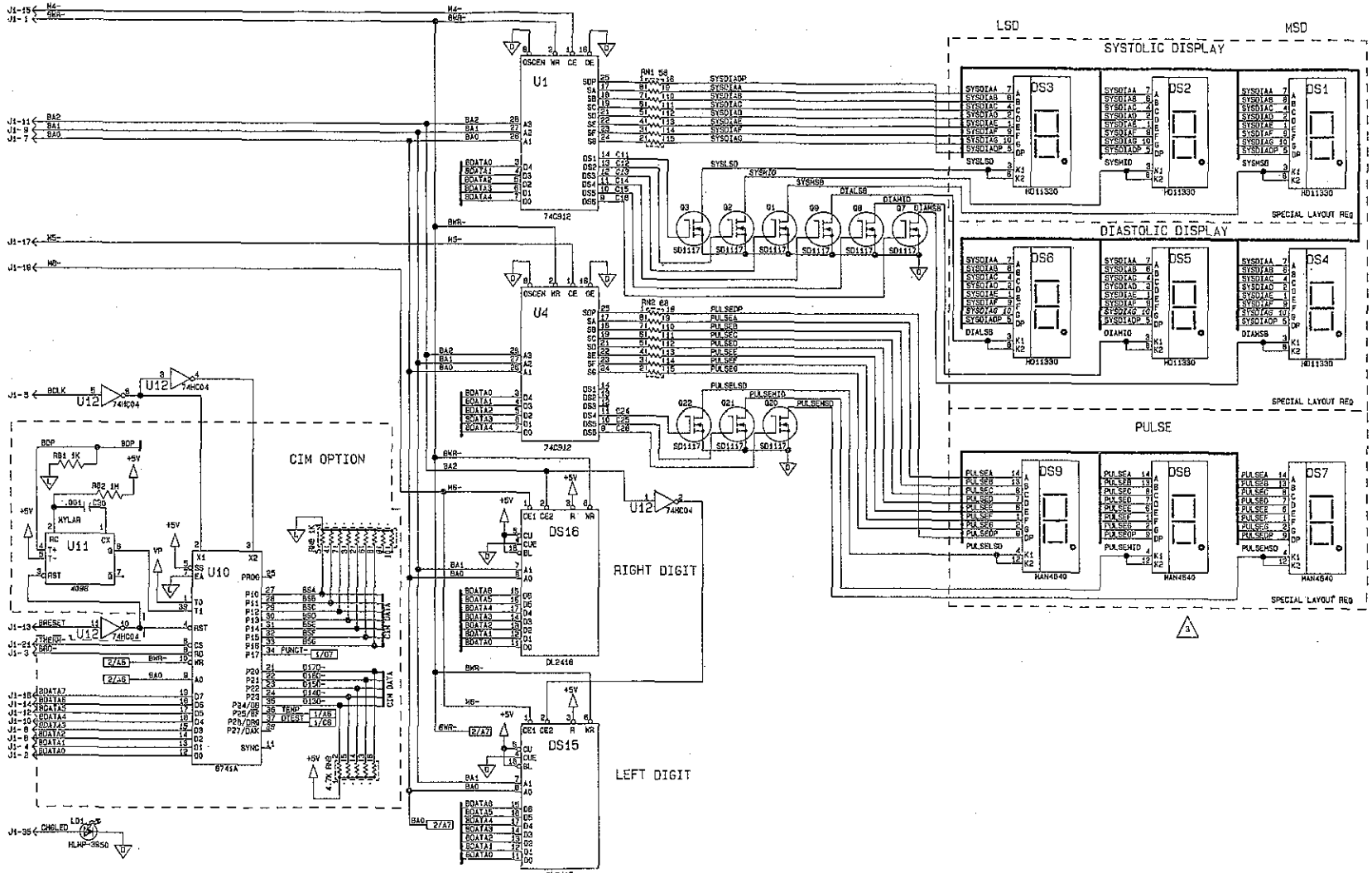

Figure 4-2. Display/Thermometer Board
(sheet 2 of 4)

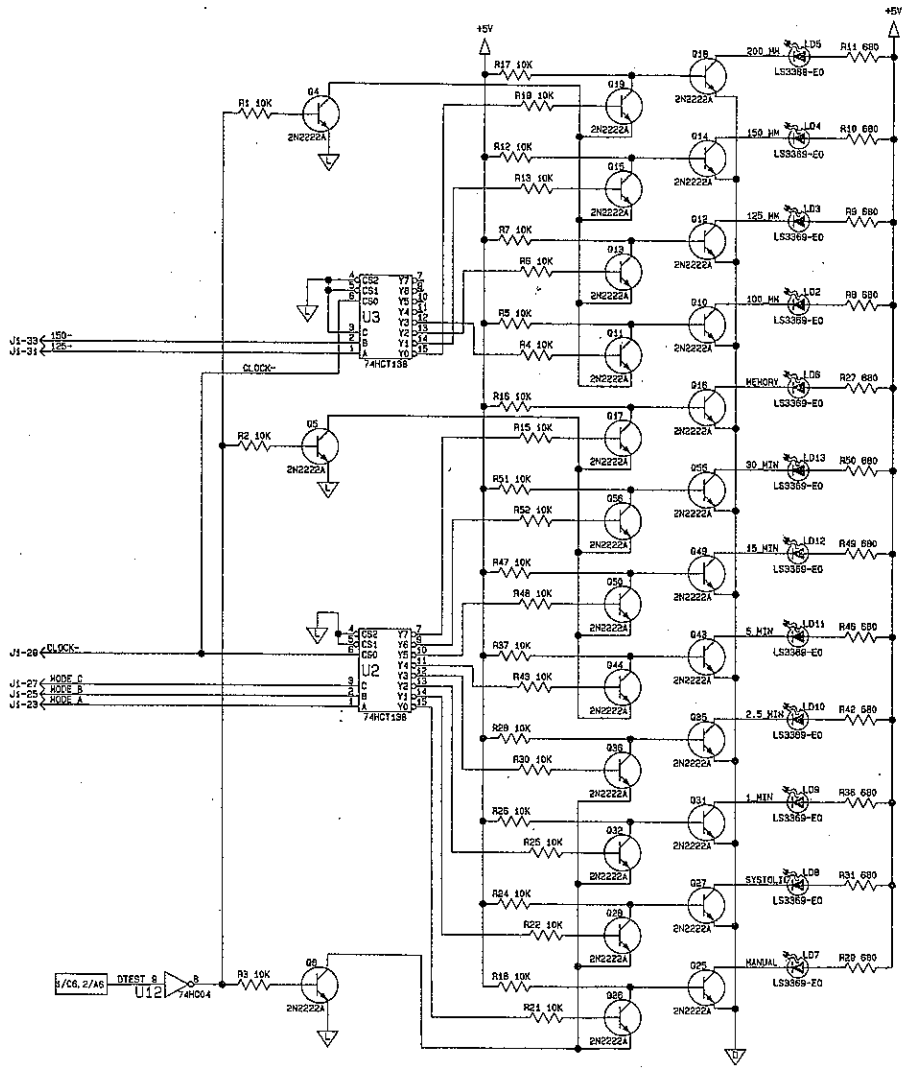

Figure 4-2. Display/Thermometer Board
(sheet 3 of 4)

NOTES (UNLESS OTHERWISE SPECIFIED):

1. RESISTOR VALUES ARE IN OHMS 1/4 WATT, 5%.
2. CAPACITOR VALUES ARE IN MICROFARADS.
3. ALL DISPLAYS ARE IN LOW PROFILE SOCKETS.
4. DISP_RTN LOG_RTN THP_RTN

HIGHEST REFERENCE DESIGNATOR USED								
U19	C33	CR9	J1	LD13	DS16	LS1	Y1	L1
Q64	RN10	RR4						

REFERENCE DESIGNATOR NOT USED								
R32-35	R38-41							

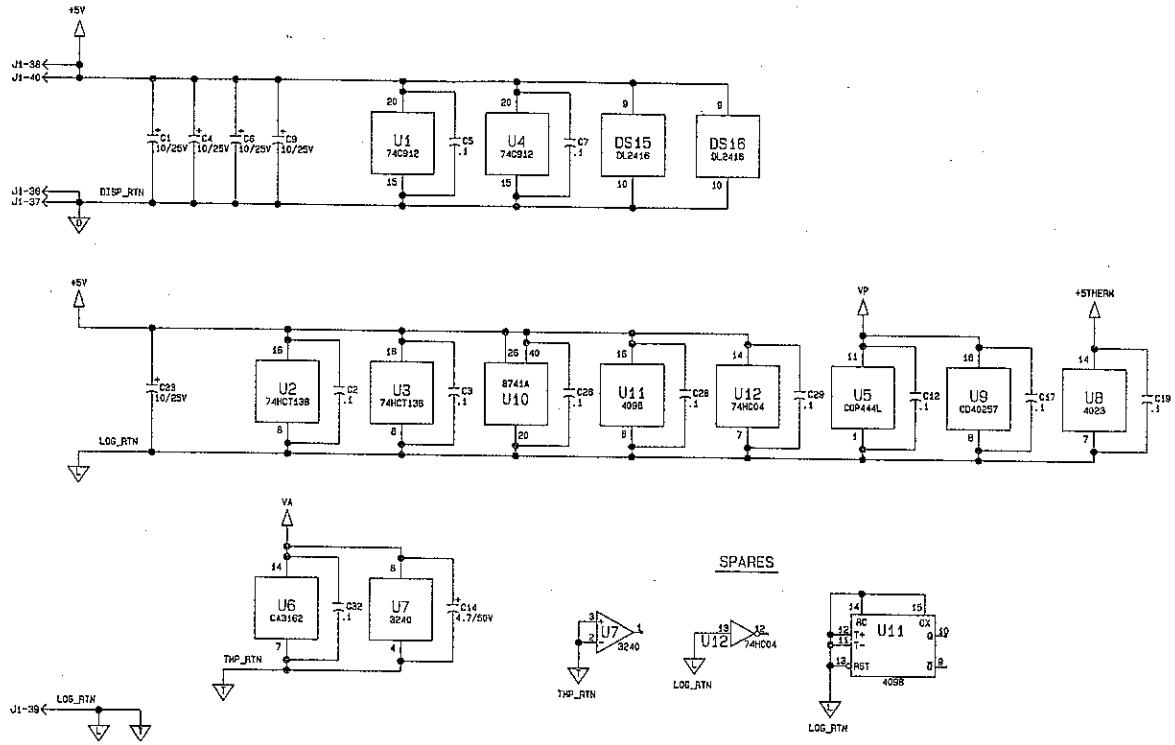

Figure 4-2. Display/Thermometer Board
(sheet 4 of 4)

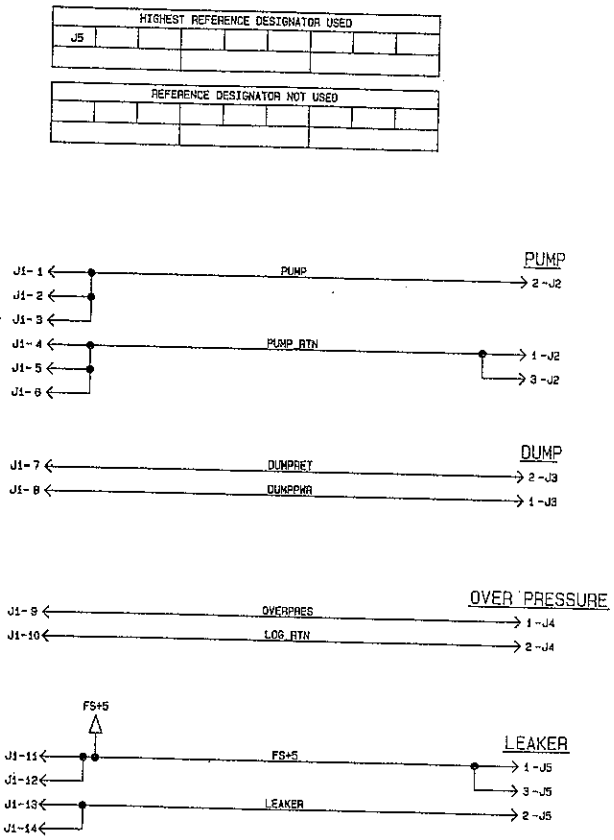

Figure 4-3. Pneumatic Transition Board

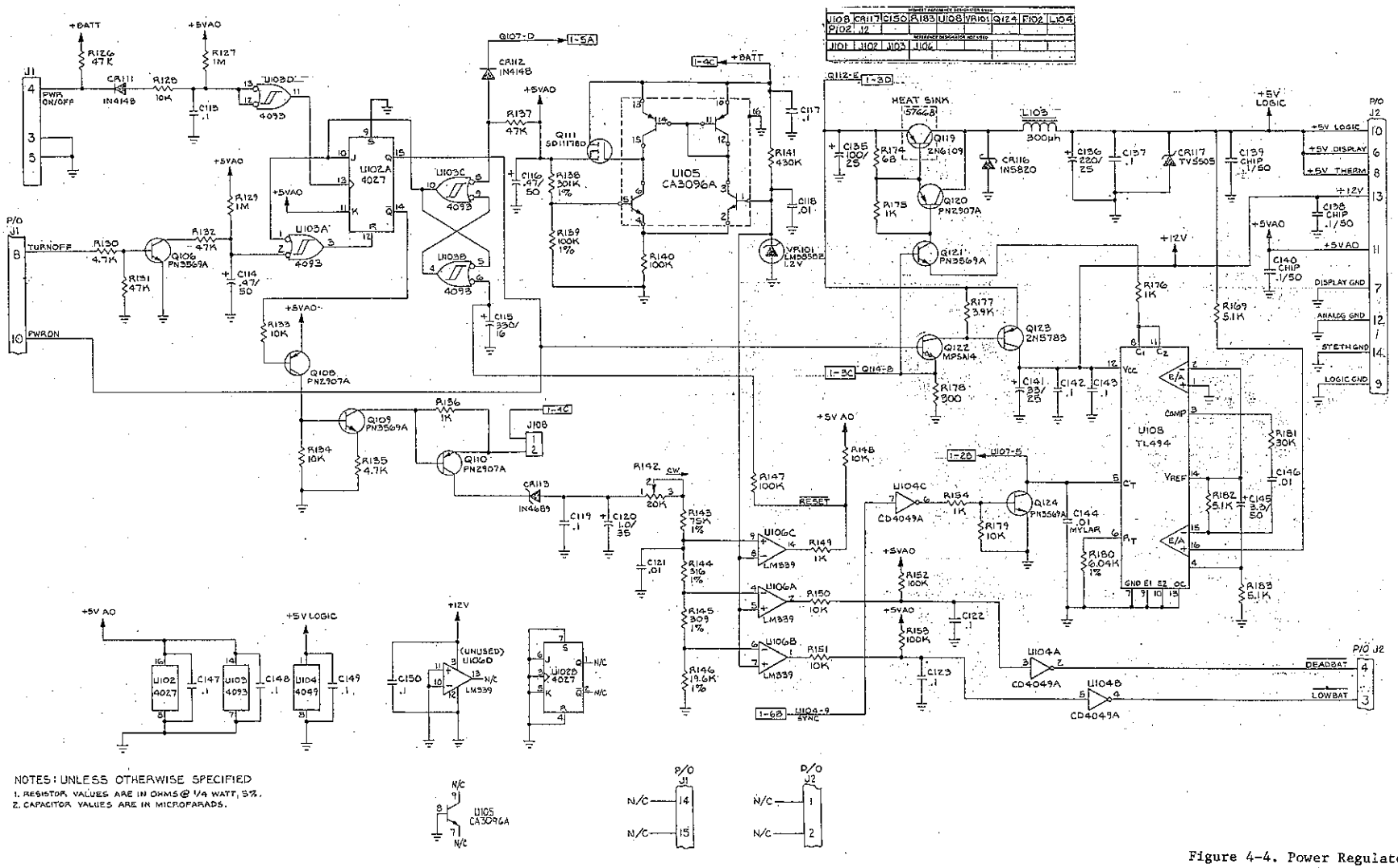

Figure 4-4. Power Regulator Board
(sheet 1 of 2)

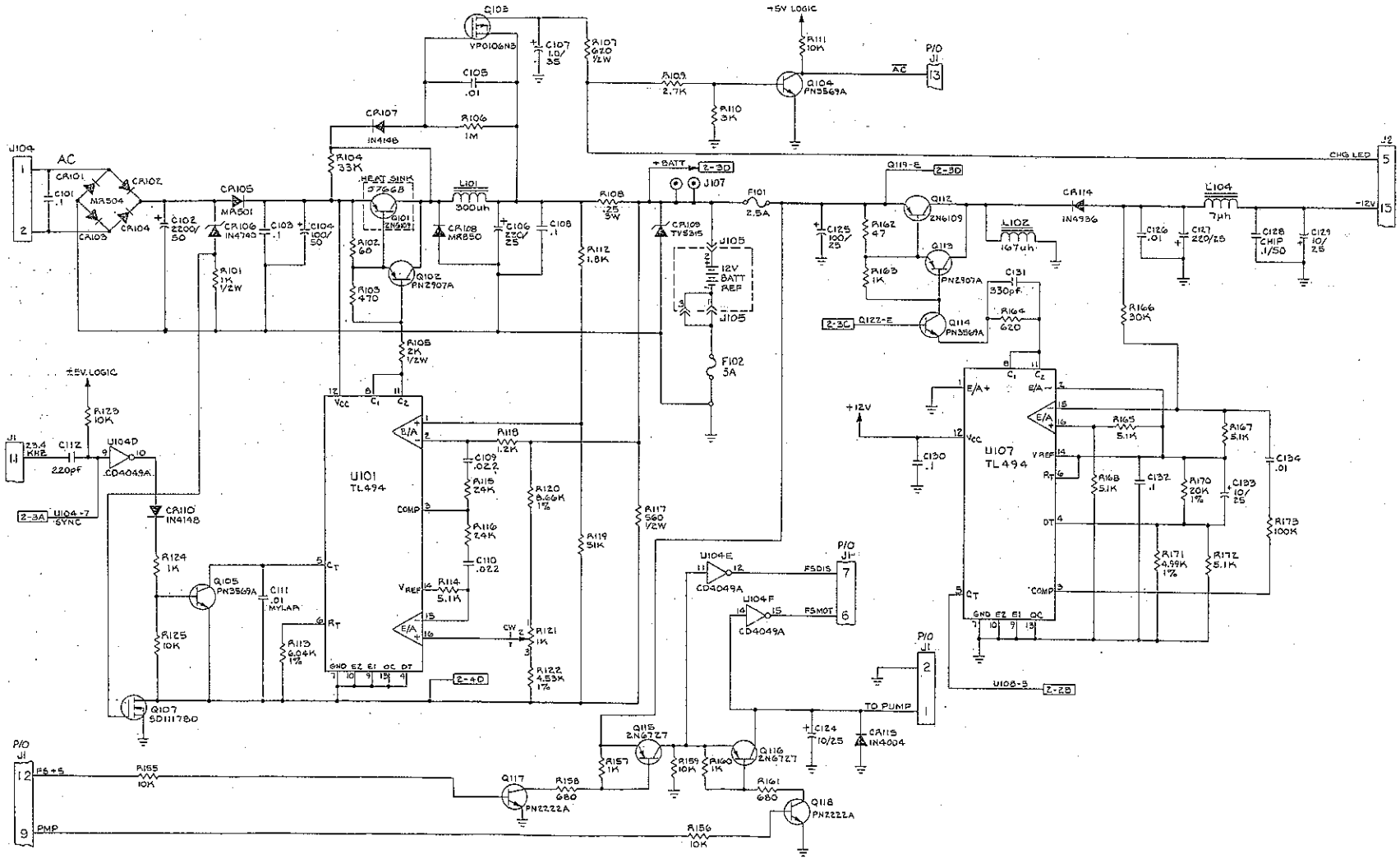

Figure 4-4. Power Regulator Board
(sheet 2 of 2)

4-26/4-27

CHAPTER FIVE - TROUBLESHOOTING

5.0 INTRODUCTION

This chapter provides help in troubleshooting the VITAL•CHECK instrument should repair be necessary. Referring to this chapter before attempting to service, repair, or replace any component will save time and may avoid unnecessary repair.

Should a problem occur, first ensure:

a. That the instrument is being operated properly.

b. The integrity of the cuff and cable.

CAUTION: Always follow static grounding procedures when troubleshooting this instrument.

Logic levels are defined as a nominal potential of +5V for a "1" or "HI" state, and zero volts for a "0," "LO," or logic ground.

The following is an outline to the tables in this chapter:

a. Table 5-1. FIX ME Alarms

b. Table 5-2. Failsafe I/O Ports

c. Table 5-3. BP System Troubleshooting Guide

d. Table 5-4. Thermometer System Troubleshooting Guide

e. Table 5-5. Power Regulator Board Voltage Specifications

f. Table 5-6. Logic/Analog Board Voltage Specifications

g. Table 5-7. Display/Thermometer Board Voltage Specifications

5.1 HARDWARE CHECKS

This instrument performs self-diagnostic hardware checks. If any of these checks fail, the CPU issues a FIX ME x message, where x is the check that failed.

The use of the FIX ME x messages for troubleshooting is explained in this section. If a FIX ME x message does not appear, continue to section 5.2.

Tests for FIX ME x conditions 0, 2, and A to K (also W to Z for the CIM equipped instruments) are run once when the instrument is turned on. Tests for 3, 4, 5, and L to N are run periodically during operation.

FIX ME conditions A to K are tests of the failsafe circuit. The CPU writes an 8-bit word to failsafe output port FAILO (U7, FS0-5). The circuit response is read back to the CPU through failsafe input port FAILI (U-18, BD0-7) and is compared with an expected value. If the expected value is not obtained, the CPU issues an alarm message to the information display, and displays an octal value in the PULSE display. This octal value corresponds to the 8-bit input from FAILI.

Table 5-1 summarizes the alarm messages. For the failsafe tests, the expected, correct binary output is shown in octal for reference. Table 5-2 shows the significance of each bit BD0-7 in the message.

Table 5-1. FIX ME Alarms

FIX ME Code	Type of Test	Expected Result Binary	Octal
0	RAM write/read check failed.		
2	EPROM CRC check failed.		
3	Attempt to execute from nonexistent memory.		
4	Pump motor on more than 100 seconds.		
5	Cuff pressure exceeded 320 mmHg.		
A	Initial power-on state not correct (pressure greater than 20 mmHg, or dump valve closed, or pump motor activated, or failsafe disconnect flipflop set, or failsafe disconnect flipflop being held clear, or incorrect pressure comparator test multiplexer channel selected).	00 110 000	060
B	Failure to detect dump valve closure or dump valve not able to be closed.	00 010 000	020
C	Failure to detect pump motor on or pump motor not able to be turned on.	00 100 000	040
D	Simulated 20 mmHg pressure sense comparator failed less than 20 mmHg simulation (FAILO Port = 00 000 001).	00 110 001	061
E	Failsafe 20 mmHg and 335 mmHg pressure sense comparators failed greater than 20 mmHg, less than 335 mmHg simulation (FAILO Port = 00 000 010).	00 111 010	072
F	Failsafe clock loss; watchdog failed clock loss simulation (FAILO Port = 00 001 000).	01 110 000	160
G	Failsafe 335 mmHg pressure sense comparator failed greater than 335 mmHg simulation (FAILO Port = 00 011 011).	01 111 011	173
H	Failsafe 4.5 minute timer high speed simulation timed out prematurely (FAILO Port = 00 011 010).	00 111 010	072

I	Failsafe 4.5 minute timer high speed simulation failed to time out within the required time (FAILO Port = 00 011 010).	01 111 010	172
J	Failsafe I/O port failed to write-lock on command from the CPU at the conclusion of power-on failsafe testing (FAILO Port = 00 100 101).	00 110 000	060
K	Failsafe disconnect flipflop failed to be reset by the CPU during power-on testing (FAILO Port = 00 000 100).	00 110 100	064
L	Pump not off or dump valve not open at idle state.	00 110 000	060
M	Pressure exceeded 20 mmHg more than 20 seconds at idle state.	00 110 000	060
N	Failsafe pressure sense 20 mmHg comparator failed to detect pressure upon cuff inflation. S2-6 probably open.		
W	I/O failure between the thermometer interface (U10) and the CPU.		
X	RAM or ROM failure in the thermometer interface (U10).		
Y	Failure of the thermometer interface (U10) to properly read the temperature display segments or digits strobes.		
Z	Failure of the thermometer interface (U10) to properly read the temperature display segments or digit strobes.		

Table 5-2. Failsafe I/O Ports

Failsafe Input Port (FAILI): U18

Bit	7	6	/	5	4	3	/	2	1	0
Mnemonic	0	FSDIS		FSDUMP	FSMOT	FSCOMP		FS2	FS1	FS0

FSDIS 0 = Failsafe OK
1 = Alarm condition, system disconnected by failsafe hardware

FSDUMP 0 = Dumper closed
1 = Dumper open

FSMOT 0 = Pump on
1 = Pump off

FSCOMP 0 = Pressure less than 20 mmHg
1 = Pressure greater than 20 mmHg

FS2-FS0 See output (changes during testing)

Failsafe Output Port (FAILO): U7

Bit	7	6	/	5	4	3	/	2	1	0
Mnemonic	0	0		FS5	FS4	FS3-		FS2	FS1	FS0

FS5 1 = Disconnect failsafe from software control

FS4	FS3-		Clock Select
0	0	=	No clock
0	1	=	90 Hz clock
1	0	=	375 Hz clock
1	1	=	Both clocks

FS2 1 = Reset flipflop, FSDIS (when under software control)

FS1, FS0 select inputs to pressure comparators

FS1	FS0		Selected Cuff Pressure
0	0	=	Actual cuff pressure (APS)
0	1	=	Simulated less than 20 mmHg
1	0	=	Simulated between 20 and 335 mmHg
1	1	=	Simulated pressure of more than 335 mmHg

The following example illustrates use of the failsafe tables, 5-1 and 5-2.

The CPU exercises the failsafe circuits on start-up as discussed in Chapter Three, section 3.8 and 3.12.3. The output port used to simulate conditions for testing is FAILO (U7, FSO-5). The CPU compares the value of the failsafe input port FAILI (U18, BDATA0-7) with an expected value. If the expected value is not read from the system, the CPU issues an alarm message to the information display, and displays an octal value in the PULSE display.

During start-up test G, the microprocessor makes FSO and FS1 HI to simulate a pressure of greater than 335 mmHg, using resistor ladder R19, R23, R30, and R37. Simultaneously, it uses FS3 and FS4 to pass through the 375 kHz clock to counter U17. FS2 is LO, removing the reset from flip/flop U25. This simulates a situation in which the software overpressure detect flag is disabled and the hardware failsafe backup is tested as described in Chapter Three, section 3.8 (step e). If the microprocessor fails to obtain the required 01111011 (173) input from U18, it alarms FIX ME G, indicating a problem with the failsafe overpressure circuit. Suspect components might include U27, U38, or one of the surrounding resistors.

5.2 TROUBLESHOOTING GUIDES

If a FIX ME message is not displayed, observe the operation of the instrument. Use table 5-3 if the instrument is inoperative and/or if a functional problem can be localized to the blood pressure measurement system. Use table 5-4 if a functional problem resides in the thermometer function.

The remainder of the tables in this chapter serve as reference guides for circuit and component level troubleshooting. Test points, test conditions, and reference voltages are provided for each of the circuit boards.

Table 5-3. BP System Troubleshooting Guide

Instrument Malfunction

Problem	Probable Cause	Solution
Instrument completely inoperative, but charge light is on when connected to AC.	Blown fuse F101.	Replace F101 and check that CR109 is not shorted on power regulator board.
	Defective 6 MHz crystal or microprocessor inoperative.	Check for 3 MHz square wave at U9-37 on logic/analog board. If voltages are correct, but no 3 MHz square wave is present, replace U9, then Y1 on board.
Instrument completely inoperative when disconnected from AC (battery only).	Dead or defective battery pack.	Replace battery pack with full charge.
	Blown fuse F102.	Replace F102 and check that CR109 is not shorted on power regulator board.
	Battery pack connectors loose.	Check integrity of battery pack connectors and harness.
	Battery trip adjustment.	Adjust R142 for 11.6V low battery alarm.
Instrument completely inoperative.	Dead electrical outlet and dead battery.	Plug into live outlet for a minimum of 3 hours before use.
	Loss of continuity in AC input circuits.	Check continuity of line cord, circuit breaker, and transformer windings.
	Defect on power regulator board.	Check power supply voltages (+12V switching regulator, U101), and power supply harness integrity. Check C116 for +5V; if not, replace or check U105 and Q111.
	No +5VAO (Reg. Bd.)	If U105-15 is 0V, replace U105. If U105-15 is 12V or more, replace Q111.

(cont.)	Circuit breaker tripped.	Reset circuit breaker.
	Circuit breaker trips repeatedly.	Check for shorted windings or shorts between windings on power transformer, or shorted CR101-CR104 on power regulator board.
Instrument inflates to other than selected pressure; instrument enters operating mode other than mode selected.	Defective U35 or U31 on logic/analog board.	Replace U35, U31.
	Defective U2 or U3 on display/thermometer board.	Replace U2 or U3.
	Defective U40 on logic/analog board.	Replace U40.
DISPLAY TEST switch inoperative.	Open connection in switch tail, or, defective switch.	Replace switch panel.
	Defective U40 on logic/analog board.	Replace U40.
High and low beep tones absent.	Defective speaker LS1 on logic/analog board.	Replace speaker if resistance does not measure 45 ±5Ω.
	Defective U26 on logic/analog board.	Replace U26 if no signal is present at pins 1 and 15 (if the 3 MHz CLK signal is present at U26-10).
	Defective Q16 and U36 on logic/analog board.	Replace Q16, then U36.
High beep tone absent.	Defective U36 and U40 on logic/analog board.	Replace U36, then U40.
	Defective U26 on logic/analog board.	Replace U26 if no signal at pin 15.

Low beep tone absent.	Defective U36 and U40 on logic/analog board.	Replace U36, then U40.
	Defective U26 on logic/analog board.	Replace U26 if no signal at pin 1.
START/RESET switch has no effect.	Failsafe 4.5 minute time-out or overpressure or other failsafe fault.	Cycle instrument's power off and on to reset instrument.
	Defective switch or broken connection in switch tail.	Replace switch panel if no continuity present.
	Defective U32 on logic/analog board.	Replace U32.
	Defective U9 on logic/analog board.	Replace U9.

Alarms

Message	Probable Cause	Solution
No flashing asterisk during blood pressure measurement, instrument always indicates BP*READY (oscillometric measurement).	Defective microphone in cuff.	Replace microphone/umbilical assembly.
	Defective U46 or associated components on logic/analog board.	Apply 100 mV, 10 Hz signal to J8 pin 2 on board and trace signal through U46 to U41. Voltage gain should be about 24.
CHECK FOR AIR LEAKS (Pump runs.)	Cuff loosely applied.	Properly apply cuff.
	Cuff improperly connected to instrument.	Properly mate cuff connector with receptacle on instrument.
	Leaky cuff.	Replace cuff.
	Internal pneumatic system leakage.	With instrument in CAL mode, manually inflate the pneumatic system with calibration fixture. The MODE SELECT switch must have the MANUAL indicator lit. One at a time, using small pliers, pinch tubes connecting to leaker, overpressure switch, and pressure transducer to isolate leak. Check reservoir assembly for air leak.
	Leaker not sealing.	Replace leaker if about 4V is present across coil (J5 on transition board). If about +5V to GND is absent at J7-11 on logic/analog board, check Q3 and associated circuitry on board. If +5V is present, but J5-2 on transition board is not less than +1V to GND, check Q7, U50, and associated components on logic/analog board. Check for open conductor in 14-conductor flat cable.

(cont.)	Overpressure switch leaking.	Replace switch.
	Dump valve leaking or not closed.	Replace manifold assembly if about 12V is present between J3-1 and 2 on transition board. If 12V is absent, check 14-conductor flat cable for an open conductor, then check Q12, Q14, and associated circuitry on logic/analog board.
	Pressure sensor leaking.	Replace pressure sensor and calibrate the pressure channel.
	Tube connecting to pressure sensor kinked.	Replace or straighten tube.
CHECK FOR AIR LEAKS (Pump does not run.)	Pump jammed.	Obstruction caught in connecting rod area on pump assembly.
	Defective pump.	Replace pump.
	No pump drive voltage.	If about 12V is not present across pump motor when attempt is made to pump, check for open conductor between J2 on transition board, and Q115, Q116, and associated components on power regulator board, then U9 and Q1 on logic/analog board.
LOW SIGNAL	Cuff improperly installed or very weak pulse.	Verify proper cuff placement. Replace microphone/umbilical assembly. Check U46, U41, and associated components on logic/analog board.

LOW SIGNAL (Instrument holds, beeps continuously, and re-pumps to higher pressures.)	Defective microphone or audio cable in cuff assembly.	Replace microphone/umbilical assembly.
	Leaker malfunction.	Perform leaker bias adjustment.
		Replace leaker. Check Q6, Q7, Q8, Q9, Q10, U50, and associated circuitry on logic/analog board. Check U43 and U42.
PATIENT MOVEMENT or ARTIFACT	Excessive patient motion.	Instruct patient to remain still.
	Poor cuff placement.	Verify correct cuff placement.
	Defective cuff.	Replace cuff.
FIX ME 0	RAM read/write error.	Replace U10, then U5, U2, U1, and U9 on logic/analog board.
FIX ME 2	ROM CRC (cyclic redundancy check) error.	Replace U1, then U5, U6, and U9 on logic/analog board.
FIX ME 3	Program jump to nonexistent memory.	Replace U9, then U1, U5, and U6 on logic/analog board.
FIX ME 4	Pump on too long or cannot be turned off.	Check for shorted Q115-Q118 on power regulator board.
		Check for shorted Q1 on logic/analog board, then replace U9 on logic/analog board.
		Check for defective U104 (FSMOT) on power regulator board.
		Replace U18 on logic/analog board.
FIX ME 5	Pressure exceeded 320 mmHg.	Cycle power ON/OFF switch and retry measurement.
		Refer to FIX ME 4, above.

FIX ME A (All references are to logic/analog board unless otherwise specified.)	Improper initial conditions/ pulse display contains octal 1XX.	Check U23-10 for logic 0. If logic 1, look for a 90 Hz square wave at U17-1, U6-6, and Q4 base. Q4 emitter should be logic 1.
		Check U108 or C136 for proper 5V level (±0.25V).
(PULSE display reads: octal 160 or 170.)		If U23-10 is logic 0, look for logic 0 at U25-1. If it is logic 1 instead of 0, check for shorted overpressure switch, defective U38, R31, R35, R38, or C45.
		Adjust overpressure switch to try to clear alarm before replacing switch.
		Check U25-12, if high, check Q2 and Q3 and replace as necessary.
		Check FS0 and FS1, if high, check Q117, Q118, and U104 pin 12 on power regulator board and replace as necessary.
		Check 14-pin ribbon cable.
		Check Q115 for open, on power regulator board.
		Check that U23-3 has a momentary logic 1, then goes to logic 0 when power is turned on.
		Check U6-6 for a 90 Hz square wave that contains no 375 kHz component.
		U38-3 should be less than 0.01V. If not, either U27, the pressure sensor, or associated components is defective, or calibration is required.

(cont.)	PULSE display contains octal number 040.	Check Q117, Q118, U104, and associated components on power regulator board.
	PULSE display contains octal number 020.	Check Q12, Q14, Q42, U28, U39, and associated components, and 14-conductor flat cable. Check dump valve coil for a resistance of 240 ±20Ω.
FIX ME B (PULSE display reads octal 060.)	Unable to close dump valve.	Defective 14-pin cable.
		Check Q12, Q14, U42, U28, U39, and associated components.
		Check dump valve coil for a resistance of 240 ±20Ω.
FIX ME C (PULSE display reads octal 060.)	Unable to start pump.	Check Q115-Q118, U104, and associated components on power regulator board.
		Check Q1 and U9.
		Replace pump assembly.
PULSE display reads octal 000.		Check dump valve (see FIX ME B also).
FIX ME D	<20 mm comparator test fail; U27-5 measures 0.05 to 0.07V.	Check U27, U38, R24, R31, and R35.
	U27-5 does not measure 0.05 to 0.07V.	Check U27, R19, R23, R30, R37, and +5V REF.
PULSE display reads octal 041.	Defective motor.	Replace pump assembly.
FIX ME E	>20 mm comparator test fail; U27-2 measures 1.50 to 1.70V.	Check U27, U38, R24, R31, and R35.
	U27-2 does not measure 1.50 to 1.70V.	Check U27, R19, R23, R30, R37, and +5V REF.

FIX ME F (PULSE display reads octal 060.)	90 Hz watchdog test failure.	Check U23, Q4, U25, and U18. Check Q115 and Q116 on power regulator board.
FIX ME G	Overpressure comparator test failure; U27-4 measures 2.40 to 2.55V.	Check U27, U38, R24, R31, and R35.
	U27-4 does not measure 2.40 to 2.55V.	Check U27, R19, R23, R30, R37, and +5V REF.
FIX ME H	Premature time-out during 4.5 minute timer test at 375 kHz.	Check U17 and U22 outputs for correct binary division of input signal.
FIX ME I	Failure to time-out during 4.5 minute timer test at 375 kHz.	Check U7, U19, U6, U17, U13, U22, and U18.
FIX ME J	Cannot write-lock output port to failsafe logic.	Check U18, U7, U13, and U3.
FIX ME K	Cannot reset U25 during failsafe logic test.	Check U7, U23, U39, and U25. NOTE: This test is interspersed among previous failsafe logic tests, with result that other conditions such as excessive offset in pressure channel or a defective pressure sensor can cause this alarm.
FIX ME L	Initial conditions (i.e., pump off, dump valve open) not attained in idle state.	Check PULSE display for incorrect bits per table 5-1. Check Q115-Q118 on power regulator board and Q12-Q14 and U25 on the logic/analog board, and associated components. Check that S2-6 is in down position or not defective.

FIX ME M	Pressure >20 mmHg for 20 seconds in idle state.	Check pressure sensor and offset adjustment in pressure channel.
	Dump valve or leaker not opening.	Check valve or leaker.
	Plugged airways or kinked tubing.	Check integrity of pneumatics.
	Excess air being squeezed from cuff during operation.	Follow operating instructions.
FIX ME N	20 mmHg comparator (U38-1) does not detect pressure when system is inflated beyond 33 mmHg.	Check U38, R43, R34, and S2-6. Check ADC (U41).

Malfunctions

Symptom	Probable Cause	Solution
All displays show dots.	No clock.	Check Y-1 for 6 MHz out.
All displays are blank.	Poor connections between logic/ analog and display/thermometer boards.	Check mating and integrity between boards.
Missing systolic, diastolic or pulse group, or wrong information in one or more digits.	Poor contacts in cable between logic/analog and display/ thermometer boards.	Check mating and integrity between boards.
	Defective U1 or U4 on display/ thermometer board.	Replace U1 if systolic/diastolic problem, or U4 if pulse problem.
	Defective U5 on logic/analog board.	Replace U5.
Missing segment in one digit.	Defective digit.	Replace digit.
Same missing or dim segment in systolic, diastolic, or pulse group.	Defective RN1 or RN2 on display/ thermometer board.	Replace RN1 if systolic/diastolic problem, or RN2 if pulse problem.
	Defective U1 or U4 on display/ thermometer board.	Replace U1 if systolic/diastolic problem, or U4 if pulse problem.
One digit completely missing or dim.	Defective transistor on display/ thermometer board.	Replace transistor corresponding to missing digits: Systolic LSD: Q3. Systolic NSD: Q2. Systolic MSD: Q1. Diastolic LSD: Q9. Diastolic NSD: Q8. Diastolic MSD: Q7. Pulse LSD: Q22. Pulse NSD: Q21. Pulse MSD: Q20.

(cont.)	Defective U1 or U4 on display/ thermometer board.	Replace U1 if systolic/diastolic digit missing or U4 if pulse digit missing.
Wrong or missing information in information display.	Poor contacts in cable between logic/analog and display/thermometer boards.	Check mating and integrity of contacts.
Missing characters or segments in information display.	Defective U5 on logic/analog board.	Replace U5.
	Defective display module (DS15 or DS16).	Replace display module.
Won't deflate.	Bias adjustment.	Perform deflation loop balance adjustment.
		Replace leaker assembly and check ADC (U41).
Cuff too loose/cuff placement.	Defective microphone or amplifier circuit.	Replace umbilical cable.
		Check U46 pins 1 and 14.

Table 5-4. Thermometer System Troubleshooting Guide

Instrument Malfunction/Alarm

Problem	Probable Cause	Solution
Thermometer completely inoperative.	Defective or contaminated DS1 or Q17 on logic/analog board.	Replace or clean DS1 or Q17.
NOTE: The entire instrument must be operational for thermometer to operate. The description refers to the display/thermometer board.	No power (+5V).	Look for +5 ±0.25V at U8-14 on display/thermometer board. Probe or tester must be plugged in.
	Defective crystal (Y1.)	Check for 2.00 MHz waveform at U5-2 with a high impedance scope. If not present, replace Y1.
	Defective U5.	If a 2.00 MHz waveform does not appear after replacing Y1, replace U5.
	Defective U8, Q37, Q38, Q45, C27, R56, CR7, CR8, or associated components.	Refer to voltage table to isolate problem. Replace suspected component.
	Defective Q57, Q63, and associated components or U40 on logic/analog board.	Check that Q57 and Q63 have gate drive when DISPLAY TEST switch is actuated.
Thermometer active but does not read temperature, or gives immediate ERR H alarm.	Defective probe.	Replace probe or substitute Model 828A thermometer tester to test thermometer.
	Defective U6, U7, U13 or associated components.	Replace U6, ensure that R84 or R83 are intact. Measure voltages at U6, U7, and U13 and compare to values on voltage table.

Turns off in 2 to 3 seconds.	Defective U8.	With an oscilloscope check that the waveform at U8-10 is an inverted likeness of U8-11, 12, and 13.
	Defective Q51 and associated circuitry.	Check to see that Q51 is keeping C21 discharged if a waveform is present at U8-10.
	Defective CR5.	Replace CR5 if no waveform is present at U8-11, 12, and 13, when in the normal and °F mode.
One blank digit in display; thermometer may turn off in 2 to 3 seconds if center digit is affected.	Defective transistors Q48, Q54, Q60, Q61, and Q64.	Replace transistor according to digit: Hundreds: Q61. Tens: Q60. Units: Q54. Tenths: Q48. Indicator: Q64.
	Defective U5.	Replace U5.
Missing segment on one digit.	Defective digit.	Replace digit.
Same segment missing or always lit on all five digits, or decimal point missing or always lit.	Defective transistor.	Replace according to affected segmented: dp: Q24, Q58. a: Q41, Q40. b: Q42, Q39. c: Q33, Q47. d: Q34, Q46. e: Q29, Q53. f: Q30, Q52. g: Q23, Q59.
	Defective RN10, RN3, RN4, or RN6.	Replace RN10, RN3, RN4, or RN6.
	Defective U5.	Replace U5.

One digit very bright and jumbled.	Short between traces.	Check for shorts.
	Defective transistors on display/ thermometer board.	Replace transistors according to affected digit: Hundreds: Q61. Tens: Q60. Units: Q54. Tenths: Q48. Indicator: Q64.
	Defective U5.	Replace U5.
Thermometer will not turn itself off.	Defective U8.	Remove probe connector, place probe into storage well, then replace probe connector. Withdraw probe from well to turn on thermometer, then replace probe in well. A negative spike should appear at U8-4, 5. If this negative spike appears, replace U8.
	Defective C20, R58.	If no negative spike appears at U8-4, 5 but U5-22 goes from logic 1 to 0, then C20 or R58 needs to be replaced.
	Defective U5.	If U5-22 stays logical 1, replace U5.
	Defective probe sense circuit.	Check DS1 or Q17.

Temperature takes 3 to 5 minutes to obtain, there is no audible tone, and F or C appears instead of rotating indicator.	Instrument is in monitor mode, or initial temperature was 94°F or above.	If entire display is flashing, thermometer is in monitor mode. Eject probe cover, set the NORMAL/MONITOR mode switch to NORMAL. Reset instrument by inserting probe into storage well. Retake temperature. If only the C or F is flashing, thermometer is in peak holding mode. This mode is activated when room and probe temperatures are higher than 34.4°C (94°F) when temperature-taking begins in normal mode. Retake temperature when temperatures are lower than 34.4°C (94°F).
Thermometer does not respond to one or both function switches.	Defective switch.	Replace switch.
	Defective CR3 or CR4 on display/ thermometer board.	Replace defective CR3 or CR4.
Thermometer turns on with unusual characters in display with only decimal point lit, or does not turn off unless probe connector is unplugged.	Defective C8, CR1, or R14.	Using ohmmeter, check for short circuits at C8 and CR1, and approximate resistance at R14 with U5 removed from socket. If short circuits are found or resistance is inappropriate, replace faulty components as needed.
	Defective U5.	Replace U5.
No audible tone.	Defective speaker or CR2.	Check the continuity of speaker with an ohmmeter. Replace if 30 to 40Ω are not obtained. If the resistance is very low, CR2 may be shorted and should be replaced.
	Defective Q62.	Check for square wave at U5-17. If present, check for square wave at collector of Q62. If square wave is not present at Q62, replace Q62.
	Defective U5.	Check for square wave at U5-17. If there is no waveform at U5-17, replace U5.

ERR 0	Defective U6.	Replace U6.
	Defective U9.	Replace U9.
ERR t	The thermometer fails to obtain a temperature within 1 minute after insertion.	Eject probe cover. Reset thermometer by returning probe to storage well. Retake temperature.
ERR L	The thermometer senses a loss of proper tissue contact within the mouth for more than 30 seconds.	Eject probe cover. Reset instrument by returning probe to storage well. Properly position probe in patient's mouth and retake temperature, holding probe base constantly. Do not allow patient to reposition probe.

Table 5-5. Power Regulator Board Voltages and Waveforms

Signal	Test Point*	Conditions	Limits
Unregulated DC voltage	C102+ U101-12	Input AC voltages: 95-135 VAC. Battery disconnected. ON/OFF switch off. 25Ω, 25W resistor connected from J107 to gnd.	18-35 VDC; ripple voltage should be <1.5V.
Regulated DC voltage	F101	Same conditions as above.	14.1 ±.1 VDC; ripple <350 mV.
Regulated DC voltage with load	F101	Nominal AC input. Battery disconnected. ON/OFF switch off. 10Ω, 50W load resistor connected to regulated DC voltage.	14.1 ±.1 VDC; ripple <350 mV.
+5VAO	J2-11 C116+	Nominal AC input; battery connected; ON/OFF switch on.	5 ±.25 VDC; ripple <100 mV.
+5V Logic	J2-10 C136	Same conditions as above.	5 ±.25 VDC; ripple <300 mV.
+14.1 Volts (+12V)	J2-13 C141	Same conditions as above.	14.1 ±.15 volts.
-12 Volts	J2-15 C-129	Same conditions as above.	-12 ±1 VDC; ripple <500 mV.
23.4 kHz	U101 pin 5	Same conditions as above.	23.4 kHz ±1 kHz sawtooth waveform about 0-3.5 VDC.
23.4 kHz	U108 pin 5	Same conditions as above.	23.4 kHz ±1 kHz sawtooth waveform about 0-3.5 VDC.
23.4 kHz	U107 pin 5	Same conditions as above.	23.4 kHz ±1 kHz sawtooth waveform about 0-3.5 VDC.

LOW BATT-	J108 (to gnd)	AC removed and battery disconnected. Low voltage DC power supply with vernier set to 14.0V connected to J105-2 and gnd. CAUTION: Observe polarity; momentarily short U103 pin 8 to gnd. (Resets latch U103.) ON/OFF switch on. Slowly lower DC supply voltage.	LOW BATT- signal goes from 5V to 0V at 11.6 ±.05 VDC.

* NOTES:

1) Unless otherwise specified, these tests are with the AC line at 120 volts, the thermometer probe removed from the instrument, MODE set in MANUAL, and all but the information display blank.

2) Logic 0 is a voltage between 0.0 and +0.2V; Logic 1 is a voltage between 4 and 5.0V.

Table 5-6. Logic/Analog Board Voltage Specifications

Unless specified, all points referred to ground:

Point	Voltage Spec.
U9-37 (CLK)	3 MHz square wave, logic 0 to logic 1
U9-36 (RST IN)	logic 1
U9-3 (RST OUT)	logic 0
U9-7 (RST7.5)	1.46 kHz square wave, logic 0 to logic 1
U9-9 (RST5.5)	logic 0 (logic 1 START/RESET actuated)
U9-8 (RST6.5)	logic 0 (with CIM Option: 1 Hz pulse, logic 0 to logic 1)
U9-4 (SOD)	logic 0 (except when pump on)
U9-6 (TRAP)	logic 0
U29-20 (CIM Option only)	+5 ±0.2 VDC
U29-2 (CIM Option only)	32.768 kHz square wave, logic 0 to logic 1
U29-18 (CIM Option only)	logic 1
U33-4 (PWR_GOOD)	logic 1
U26-1 (LOW TONE)	732 Hz square wave, logic 0 to logic 1
U26-15 (HIGH TONE)	1.46 kHz square wave, logic 0 to logic 1
U26-4 (POWER SUPPLY CLOCK)	23.4 kHz square wave, logic 0 to logic 1
U26-6 (A/O CLOCK, FAILSAFE CLOCK)	375 kHz square wave, logic 0 to logic 1
U40-10 (TURN OFF)	logic 0
U40-12 (TEMP)	logic 1 (probe removed from well)
U40-13 (DTEST)	logic 0
U40-23 (DEADBAT-)	logic 1 (battery charged)

U40-24 (LOWBATT-)	logic 1 (battery charged)
U40-25 (AC-)	logic 0 (when plugged into AC)
U36-10 (AUDIO)	logic 0 (no audio present)
U17-1	91.6 Hz square wave, logic 0 to logic 1
U17-12 (4.5 MIN TIMER CLOCK)	45.8 Hz square wave, logic 0 to logic 1
U17-4	1.43 Hz square wave, logic 0 to logic 1
U17-2	logic 0
U25-4	logic 1 (not allowed to clock a 1 to second stage)
U25-8	logic 0
U25-12	logic 1 (FS+5 activated to enable dumper, leaker, and pump control circuits)
U25-10	logic 0
U23-2 (FS2-)	logic 1
U23-1	logic 1
U23-11	logic 1
U23-4	logic 0
U22-11	logic 1
U22-2 and U22-3 (4.5 MIN TIMER)	logic 0 (both HI at the end of 4.5 MIN)
U3-3	logic 0
U13-9	logic 1
U27-1 (To ANALOG GROUND)	0.0 ±0.024 VDC (system deflated)

Unless specified, all points referred to analog ground (U41-16):

Point	Voltage Spec.
U27-5	0.058 ±0.004 VDC
U27-2	1.60 ±0.010 VDC
U27-4	2.39 ±0.180 VDC
U38-1	logic 0 (system deflated <20 mmHg)
U38-7	logic 1 (system <335 mmHg)
U38-3	0.0 ±0.024 VDC (system deflated)
U38-2	0.118 ±0.010 VDC (reference)
U38-5	1.99 ±0.15 VDC (reference)

Pin or Lead Position	Voltage Spec.
From U42-14 to U42-7	logic 0
From U42-15 to U42-7	logic 0
From U42-16 to U42-7	logic 0
Q14 collector	12.7 ±1.7 VDC (dumper open)
U41-28 (APS)	0.0 ±0.02 VDC (idle state)
U41-27 (RPS)	2.5 ±0.25 VDC (idle state)
U41-26 (MICS)	2.5 ±0.25 VDC (idle state)
From U41-10 to U42-7	375 kHz square wave, logic 0 to logic 1
U46-14	0.0 ±0.04 VDC

Unless specified, all points referred to ground:

Point	Voltage Spec.
From U46-9 to VR2 "OUT"	0.050 to 0.125 VDC
U46-6	-0.1 ±0.025 VDC
VR2 "OUT" (+5VDC REF)	4.75 to 5.15 VDC
U44-2	1.22 to 1.25 VDC
U45-1 (APS)	0.0 ±0.024 VDC (system deflated)
U45-5	1.22 to 1.25 VDC
U50-1	0.0 ±0.5 VDC
U50-5 (-LIM)	-0.1 ±0.025 VDC
From U50-10 (+LIM) to VR2 "OUT"	0.050 to 0.125 VDC
U50-12	1.5 ± 0.5 VDC
U50-14	5.5 to 7.0 VDC

Table 5-7. Display/Thermometer Board Voltage Specifications

Unless specified, all points referred to ground:

Point	Voltage Spec.
U1-20	+5 ±0.25 VDC
U10-2 (CIM Option only)	3 MHz square wave, logic 0 to logic 1
U10-3 (CIM Option only)	3 MHz square wave, logic 0 to logic 1
U10-4 (CIM Option only)	logic 1
U10-39 (CIM Option only)	logic 0

Thermometer completely inoperative; unless specified, all points referred to ground:

Point	Expected Voltage	Probable Defective Item
U8-14	4.75 to 5.25 VDC	Probe Connector
U8-10	Waveform, logic 0 to logic 1	U8
Q37-C	0 to 0.1 VDC	Q37
U5-11 (VP)	4.75 to 5.25 VDC	Q45
U7-8 (VA)	4.75 to 5.25 VDC	Q38
U5-4 (RST)	4.75 to 5.25 VDC	C8, U5, or R14
Q57-D	0 VDC	Q57 on display/thermometer board, DS1 or Q17 on logic/ analog board

Thermometer does not read temperature; unless specified, all points referred to ground.

Point	Expected Voltage	Probable Defective Item
U5-23 (PROBE SENSOR IN)	1.2 to 1.4 VDC	CR7, CR8, or C15
U8-9	4.75 to 5.25 VDC	U8, C27, or R56
U7-8	4.75 to 5.25 VDC	Q38
U7-7 (TEMP SIGNAL)	1 VDC or less	U7
U13	OUT 1.23 VDC > REF	U13
U6-10	0.1 VDC or less	R67
U8-11, 12, and 13	0 to 5 VDC pulses	U8 or R61